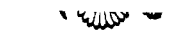
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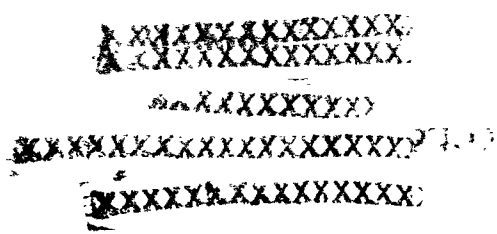
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towards

The People of India



ANNUAL REPORT OF THE BOARD OF REGENTS OF

THE SMITHSONIAN INSTITUTION

SHOWING THE

OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR ENDED JUNE 30

1941



(Publication 3651)

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LETTER OF TRANSMITTAL

SMITHSONIAN INSTITUTION,
Washington, December 3, 1941.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ended June 30, 1941. I have the honor to be,

Very respectfully, your obedient servant,

C. G. ABBOT, *Secretary.*

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THE SMITHSONIAN INSTITUTION

June 30, 1941

Presiding officer ex officio.—FRANKLIN D. ROOSEVELT, President of the United States.

Chancellor—CHARLES EVANS HUGHES, Chief Justice of the United States.

Members of the Institution:

FRANKLIN D. ROOSEVELT, President of the United States.
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CHARLES EVANS HUGHES, Chief Justice of the United States.
CORDELL HULL, Secretary of State.
HENRY MORGENTHAU, Jr., Secretary of the Treasury.
HENRY L. STIMSON, Secretary of War.
ROBERT H. JACKSON, Attorney General.
FRANK C. WALKER, Postmaster General.
FRANK KNOX, Secretary of the Navy.
HAROLD L. ICKES, Secretary of the Interior.
CLAUDE R. WICKARD, Secretary of Agriculture.
JESSE H. JONES, Secretary of Commerce.
FRANCES PERKINS, Secretary of Labor.

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ALBEN W. BARKLEY, Member of the Senate.
BENNETT CHAMP CLARK, Member of the Senate.
CLARENCE CANNON, Member of the House of Representatives.
WILLIAM P. COLE, Jr., Member of the House of Representatives.
FOSTER STEARNS, Member of the House of Representatives.
FREDERIC A. DELANO, citizen of Washington, D. C.
ROLAND S. MORRIS, citizen of Pennsylvania.
HARVEY N. DAVIS, citizen of New Jersey.
ARTHUR H. COMPTON, citizen of Illinois.
VANNEVAR BUSH, citizen of Washington, D. C.

Executive committee.—FREDERIC A. DELANO, VANNEVAR BUSH.

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Assistant Secretary.—ALEXANDER WETMORE.

Administrative assistant to the Secretary.—HARRY W. DORSEY.

Treasurer.—NICHOLAS W. DORSEY.

Chief, editorial division.—WEBSTER P. TRUE.

Librarian.—WILLIAM L. CORBIN.

Personnel officer.—HELEN A. OLMSTED.

Property clerk.—JAMES H. HILL.

UNITED STATES NATIONAL MUSEUM

Keeper ex officio.—CHARLES G. ABBOT.
Assistant Secretary (in charge).—ALEXANDER WETMORE.
Associate Director.—JOHN E. GRAF.

SCIENTIFIC STAFF

DEPARTMENT OF ANTHROPOLOGY:

Frank M. Setzler, head curator; A. J. Andrews, chief preparator.

Division of Ethnology: H. W. Krieger, curator; J. E. Weckler, Jr., assistant curator; Arthur P. Rice, collaborator.

Section of Ceramics: Samuel W. Woodhouse, collaborator.

Division of Archeology: Neil M. Judd, curator; Waldo R. Wedel, assistant curator; R. G. Paine, senior scientific aid; J. Townsend Russell, honorary assistant curator of Old World archeology.

Division of Physical Anthropology: Aleš Hrdlička, curator; T. Dale Stewart, associate curator.

Collaborators in anthropology: George Grant MacCurdy; W. W. Taylor, Jr.

DEPARTMENT OF BIOLOGY:

Leonhard Stejneger, head curator; W. L. Brown, chief taxidermist; Aime M. Awl, illustrator.

Division of Mammals: Remington Kellogg, curator; H. Harold Shamel, senior scientific aid; A. Brazier Howell, collaborator; Gerrit S. Miller, Jr., associate.

Division of Birds: Herbert Friedmann, curator; J. H. Riley, associate curator; H. G. Deignan, assistant curator; Alexander Wetmore, custodian of alcoholic and skeleton collections; Casey A. Wood, collaborator; Arthur C. Bent, collaborator.

Division of Reptiles and Batrachians: Leonhard Stejneger, curator; Doris M. Cochran, assistant curator.

Division of Fishes: Leonard P. Schultz, curator; E. D. Reid, senior scientific aid.

Division of Insects: L. O. Howard, honorary curator; Edward A. Chapin, curator; R. E. Blackwelder, assistant curator; William Schaus, honorary assistant curator.

Section of Hymenoptera: S. A. Rohwer, custodian; W. M. Mann, assistant custodian; Robert A. Cushman, assistant custodian.

Section of Myriapoda: O. F. Cook, custodian.

Section of Diptera: Charles T. Greene, assistant custodian.

Section of Coleoptera: L. L. Buchanan, specialist for Casey collection.

Section of Lepidoptera: J. T. Barnes, collaborator.

Section of Hemiptera: W. L. McAtee, acting custodian.

Section of Forest Tree Beetles: A. D. Hopkins, custodian.

Division of Marine Invertebrates: Waldo L. Schmitt, curator; C. R. Shoemaker, assistant curator; James O. Maloney, aid; Mrs. Harriet Richardson Searle, collaborator; Max M. Ellis, collaborator; J. Percy Moore, collaborator; Joseph A. Cushman, collaborator in Foraminifera; Charles Branch Wilson, collaborator in Copepoda.

Division of Mollusks: Paul Bartsch, curator; Harald A. Rehder, assistant curator; Joseph P. E. Morrison, senior scientific aid.

Section of Helminthological Collections: Benjamin Schwartz, collaborator.

Division of Echinoderms: Austin H. Clark, curator.

DEPARTMENT OF BIOLOGY—Continued.

Division of Plants (National Herbarium): W. R. Maxon, curator; Ellsworth P. Killip, associate curator; Emery C. Leonard, assistant curator; Conrad V. Morton, assistant curator; Egbert H. Walker, aid; John A. Stevenson, custodian of C. G. Lloyd mycological collection.

Section of Grasses; Agnes Chase, custodian.

Section of Cryptogamic Collections; O. F. Cook, assistant curator.

Section of Higher Algae: W. T. Swingle, custodian.

Section of Lower Fungi: D. G. Fairchild, custodian.

Section of Diatoms: Paul S. Conger, custodian.

Associates in Zoology: C. Hart Merriam, Mary J. Rathbun, Theodore S. Palmer, William B. Marshall, A. G. Böving.

Associate curator in Zoology: Hugh M. Smith.

Associate in Marine Sediments: T. Wayland Vaughan.

Collaborator in Zoology: Robert Sterling Clark.

Collaborators in Biology: A. K. Fisher, David C. Graham.

DEPARTMENT OF GEOLOGY:

R. S. Bassler, head curator; Jessie G. Beach, aid.

Division of Physical and Chemical Geology (systematic and applied): W. F. Foshag, curator; Edward P. Henderson, assistant curator; Bertel O. Reberholt, senior scientific aid.

Division of Mineralogy and Petrology: W. F. Foshag, curator; Frank L. Hess, custodian of rare metals and rare earths.

Division of Stratigraphic Paleontology: Charles E. Resser, curator; Gustav A. Cooper, assistant curator; Marion F. Willoughby, senior scientific aid.

Section of Invertebrate Paleontology: T. W. Stanton, custodian of Mesozoic collection; Paul Bartsch, curator of Cenozoic collection.

Division of Vertebrate Paleontology: Charles W. Gilmore, curator; C. Lewis Gazin, assistant curator; Norman H. Boss, chief preparator.

Associates in Mineralogy: W. T. Schaller, S. H. Perry.

Associate in Paleontology: E. O. Ulrich.

Associate in Petrology: Whitman Cross.

DEPARTMENT OF ENGINEERING AND INDUSTRIES:

Carl W. Mitman, head curator.

Division of Engineering: Frank A. Taylor, curator.

Section of Transportation and Civil Engineering: Frank A. Taylor, in charge.

Section of Aeronautics: Paul E. Garber, assistant curator.

Section of Mechanical Engineering: Frank A. Taylor, in charge.

Section of Electrical Engineering and Communications: Frank A. Taylor, in charge.

Section of Mining and Metallurgical Engineering: Carl W. Mitman, in charge.

Section of Physical Sciences and Measurement: Frank A. Taylor, in charge.

Section of Tools: Frank A. Taylor, in charge.

Division of Crafts and Industries: Frederick L. Lewton, curator; Elizabeth W. Rosson, senior scientific aid.

Section of Textiles: Frederick L. Lewton, in charge.

Section of Woods and Wood Technology: William N. Watkins, assistant curator.

Section of Chemical Industries: Wallace E. Duncan, assistant curator.

Section of Agricultural Industries: Frederick L. Lewton, in charge.

DEPARTMENT OF ENGINEERING AND INDUSTRIES—Continued.

Division of Medicine and Public Health: Charles Whitebread, associate curator.

Division of Graphic Arts: R. P. Tolman, curator.

Section of Photography: A. J. Olmsted, assistant curator.

DIVISION OF HISTORY: T. T. Belote, curator; Charles Carey, assistant curator; Catherine L. Manning, philatelist.

ADMINISTRATIVE STAFF

Chief of correspondence and documents.—H. S. BRYANT.
Assistant chief of correspondence and documents.—L. E. COMMERFORD.
Superintendent of buildings and labor.—R. H. TREMBLY.
Assistant superintendent of buildings and labor.—CHARLES C. SINCLAIR.
Editor.—PAUL H. OEHSER.
Accountant and auditor.—N. W. DORSEY.
Photographer.—A. J. OLMSTED.
Property clerk.—LAWRENCE L. OLIVER.
Assistant librarian.—LEILA F. CLARK.

NATIONAL GALLERY OF ART

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THE SECRETARY OF THE TREASURY.
THE SECRETARY OF THE SMITHSONIAN INSTITUTION.
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Chief Curator.—JOHN WALKER.

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FREER GALLERY OF ART

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Assistant Director.—GRACE DUNHAM GUEST.
Associate in archeology.—CARL WHITING BISHOP.
Associate in research.—ARCHIBALD G. WENLEY.
Superintendent.—W. N. RAWLEY.

BUREAU OF AMERICAN ETHNOLOGY

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Senior ethnologists.—H. B. COLLINS, Jr., JOHN P. HARRINGTON, JOHN R. SWANTON.
Senior archeologist.—FRANK H. H. ROBERTS, Jr.
Senior anthropologist.—JULIAN H. STEWARD.
Associate anthropologist.—W. N. FENTON.
Editor.—M. HELEN PALMER.
Librarian.—MIRIAM B. KETCHUM.
Illustrator.—EDWIN G. CASSEDY.

INTERNATIONAL EXCHANGE SERVICE

Secretary (in charge).—CHARLES G. ABBOT.
Chief Clerk.—COATES W. SHOEMAKER.

NATIONAL ZOOLOGICAL PARK

Director.—WILLIAM M. MANN.
Assistant Director.—ERNEST P. WALKER.

ASTROPHYSICAL OBSERVATORY

Director.—CHARLES G. ABBOT.
Assistant Director.—LOYAL B. ALDRICH.
Senior astrophysicist.—WILLIAM H. HOOVER.

DIVISION OF RADIATION AND ORGANISMS

Director.—CHARLES G. ABBOT.
Assistant Director.—EARL S. JOHNSTON.
Senior physicist.—EDWARD D. MCALISTER.
Senior mechanical engineer.—LELAND B. CLARK.
Associate plant physiologist.—FLORENCE M. CHASE.
Junior biochemist.—ROBERT L. WEINTRAUB.

REPORT OF THE SECRETARY OF THE SMITHSONIAN INSTITUTION

C. G. ABBOT

FOR THE YEAR ENDED JUNE 30, 1941

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: I have the honor to submit herewith my report showing the activities and condition of the Smithsonian Institution and the Government bureaus under its administrative charge during the fiscal year ended June 30, 1941. The first 18 pages contain a summary account of the affairs of the Institution, and appendixes 1 to 11 give more detailed reports of the operations of the National Museum, the National Gallery of Art, the National Collection of Fine Arts, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, the Division of Radiation and Organisms, the Smithsonian library, and of the publications issued under the direction of the Institution. On page 130 is the financial report of the executive committee of the Board of Regents.

OUTSTANDING EVENTS

Among the numerous bureaus and agencies in Washington, certain ones are listed as defense agencies, and the Smithsonian Institution was included during the year in this list. Its vast collections are of great usefulness in the identification and study of strategic materials relating to national defense, such as rubber, tin, aluminum, mica, optical glass, abrasives, and many others. Its staff includes scientific experts and technicians with outstanding experience in connection with such materials, as well as laboratories and equipment for all sorts of delicate experimental work. The Smithsonian has already been assigned a number of defense problems and stands ready to devote all its resources to such work when called upon.

The National Gallery of Art was completed and opened to the public in March 1941, bringing to fruition the late Andrew W. Mellon's gift to the Nation of his priceless art collection and a magnificient building to house it.

The great hall of the Smithsonian Building was completely redecorated, and in it was installed a unique exhibit designed to

illustrate concisely for visitors all the activities of the Institution and its branches. Opened in January 1941, after a preview by the Board of Regents, the new exhibit aroused widespread favorable comment.

The Smithsonian radio program, "The World is Yours," on June 14, 1941, put on the air an anniversary broadcast marking the completion of 5 full years of the series. A tabulation of station-manager ratings of the program showed that its popularity throughout the country continued unabated.

Among several bequests to the Institution announced during the year, the largest was that from Mrs. Mary Vaux Walcott, widow of the late Secretary Charles D. Walcott. Her bequest amounted to more than $400,000.

New members on the Board of Regents were Vice President Henry A. Wallace, and Representative Foster Stearns, of New Hampshire.

The revision of all solar-constant values collected by the Astrophysical Observatory from all Smithsonian observing stations from 1923 to the present proved to be an even more tremendous task than had been anticipated. It was nearing completion, however, at the close of the year, and publication is expected to begin by the first part of 1942.

M. W. Stirling made further archeological discoveries in southern Mexico, working in cooperation with the National Geographic Society. Dr. Frank H. H. Roberts, Jr., conducted his sixth and final archeological expedition to the Lindenmeier site in northern Colorado, his work having added greatly to our knowledge of Folsom man and the whole subject of the early occupation of America.

The work of the International Exchange Service was seriously hampered by world conditions, but the scientific and other publications intended for foreign exchange that cannot now be sent are being stored at the Institution until the end of hostilities.

SUMMARY OF THE YEAR'S ACTIVITIES OF THE BRANCHES OF THE INSTITUTION

National Museum.—Appropriations for the maintenance and operation of the Museum during the fiscal year amounted to $818,305. Additional funds are needed annually for guards, curators, and improvements, but in the press of defense needs the Congress has not found it expedient to grant them. Accessions for the year totaled 326,686 individual specimens, bringing the number of catalog entries in all departments of the Museum to nearly 17,500,000. Among the outstanding things received were the following: In anthropology, a collection of Paleolithic, Neolithic, and Bronze Age implements

and ornaments from Java, nearly 1,000 potsherds and shell implements from Indian burial mounds near Belle Glade, Fla., skeletal remains from Peru, and a reconstruction of the newly found remains of the fourth *Pithecanthropus*; in biology, 74 mammals, 472 reptiles and amphibians, and nearly 2,000 fishes from Liberia, all resulting from the Smithsonian-Firestone Expedition to that country, the Nevermann collection of about 33,000 Costa Rican Coleoptera including much type material, and a large collection of marine invertebrates resulting from the participation of Dr. Waldo L. Schmitt in the Fish and Wildlife Service's investigations of the Alaska king crab; in geology, an 1,800-carat aquamarine crystal from Agua Preta, Brazil, the Sardis, Ga., meteorite, weighing 1,760 pounds. the fifth largest ever found in the United States, many thousands of Cambrian, post-Cambrian, and Devonian fossils collected in various parts of the United States by members of the Museum staff, and the greater part of a fossil skeleton of the primitive mammal *Uintatherium*; in engineering and industries, an operating exhibit of the Westinghouse air brake, a fighter plane known as the Curtiss Sparrowhawk, and a 93-dial display clock made by Louis Zimmer, of Lier, Belgium, which tells the time at many places around the world, the tides at various points, and many calendar and astronomical events; in history, busts, costumes, or mementos of famous Americans including Abraham Lincoln, William Jennings Bryan, and Brig. Gen. Caleb Cushing. As usual, many members of the scientific staff took part in field expeditions, financed for the most part by Smithsonian private funds or through cooperative arrangements with other organizations or individuals. Twenty-five publications were issued by the Museum, and 52,170 copies of its publications were distributed. Visitors for the year totaled 2,505,871. Fourteen special exhibits were held under the auspices of various educational, scientific, and other groups. Changes in staff included the retirement of Gerrit S. Miller, Jr., as curator of the division of mammals and the advancement of the assistant curator, Dr. Remington Kellogg, to succeed him, and the appointment of two new assistant curators, Dr. Joseph E. Weckler, Jr., in the division of ethnology, and Dr. Richard E. Blackwelder in the division of insects.

National Gallery of Art.—The completed building of the National Gallery of Art was formally accepted by the trustees of the Gallery on December 10, 1940, and on the evening of March 17, 1941, the opening ceremonies were held. Chief Justice Charles Evans Hughes briefly described the purposes of the Gallery, Mr. Paul Mellon, son of the donor of the Gallery, presented the building and the Mellon Collection to the Nation, and Mr. Samuel H. Kress presented the Kress Collection to the Gallery. The President of the United States

then accepted the Gallery on behalf of the people of the Nation. The following day the building was opened to the public, and the attendance from that day to June 30 was 798,156, an average of 7,529 per day. Practically all the initial staff of the Gallery had been employed by March 1, 1941, the number of employees on June 30 being 229. The first catalog of the Gallery and a booklet of general information were ready for distribution at the time of the public opening, as were also a book of illustrations of all the art works in the collection, color reproductions, and postcards. A number of important prints and four paintings were accepted as gifts during the year. Under the educational program of the Gallery, the docent staff has been organized so that there are at least two public gallery tours every day and two auditorium lectures every week. A memorial tablet to the late Andrew W. Mellon, donor of the Gallery, was installed in the lobby, and four marble panels were set aside for the names of important donors to the Gallery. The names at present carved on the panels are those of Mr. Mellon and Samuel H. Kress, and the names of future donors will be added as authorized by the Board of Trustees.

National Collection of Fine Arts.—The National Collection received two additions to its endowment funds during the year: $5,000 from the Cornelia Livingston Pell Estate of New York, and $10,000 from the Miss Julia D. Strong Estate, of Washington, D. C. Three paintings were accepted for the National Collection by the Smithsonian Art Commission in December 1940, and several other gifts of etchings, miniatures, and paintings were deposited during the year to be passed upon by the Commission at its next annual meeting. Three miniatures were purchased through the Catherine Walden Myer Fund. The following eight special exhibitions were held: 48 pastels, drawings, and lithographs by Lily E. Smulders; the Sixth Annual Metropolitan State Art Contest, 1940, comprising 289 art works by 158 artists; the work of William Baxter Closson (1848–1926), comprising 94 oils, 40 pastels, 21 water colors, 112 wood engravings, and other material; 111 pastels by 17 artists, exhibited by the National Society of Pastelists; 22 water colors and 21 pastels by Ethel H. Hagen; 42 paintings by Alejandro Pardinas under the patronage of the Cuban Ambassador; 39 caricatures by Antonio Sotomayor under the patronage of the Bolivian Minister; and a memorial exhibition of 17 color prints and 50 black and white prints by Bertha E. Jaques (1863–1941). A new edition of the Catalog of American and European Paintings in the Gellatly Collection was published.

Freer Gallery of Art.—Additions to the collections included Chinese bronze, Chinese jade, Arabic manuscripts, Indian and Per-

sian painting, Chinese porcelain, and Chinese and Persian pottery. The work of the curatorial staff was devoted to the study and recording of these new acquisitions and other art objects and manuscripts already in the collection. In addition 693 objects and 180 photographs were brought or sent to the Director for information concerning them, and reports upon all these were made to the owners. Changes in exhibition involved 84 individual objects. Visitors to the Gallery totaled 111,784 for the year. Six illustrated lectures were given in the auditorium, six study groups were held in a study room and ten groups were given docent service in exhibition galleries. A. G. Wenley of the Gallery staff gave a 6 weeks' lecture course in Chinese and Japanese art in the Far Eastern Institute at the 1940 Harvard University Summer School. William R. B. Acker, also of the staff, returned from Holland, having taken his Ph.D. *cum laude* in Chinese at the University of Leyden.

Bureau of American Ethnology.—The Chief of the Bureau, M. W. Stirling, continued his archeological excavations in southern Mexico in cooperation with the National Geographic Society. At Cerro de las Mesas 20 carved stone monuments were unearthed, and 2 initial series dates were deciphered. At Izapa, a link between the west coast of Guatemala and the isthmian region of southern Mexico, a large number of stelae were excavated. The collections made were brought to Mexico City, where they were studied by Dr. Philip Drucker, assistant archeologist of the expedition. Dr. J. R. Swanton brought to completion his extensive report on the Indians of the Southeast, comprising 1,500 typewritten pages, which the Bureau plans to publish shortly. Three other ethnological papers by Dr. Swanton were in process of publication. Dr. J. P. Harrington continued his comparative study of the Navaho and Tlingit languages. His work on the Navaho was completed during the year, forming a manuscript of more than 1,200 pages. Dr. F. H. H. Roberts, Jr., brought to completion the sixth and final season of archeological investigations at the Lindenmeier site in northern Colorado, wherein much new and valuable information on the subject of Folsom man and the early occupation of North America has been obtained. Toward the close of the year he went to San Jon, N. Mex., to start excavations at a promising site suggestive of another phase of early man in North America, the so-called Yuma. Dr. J. H. Steward completed his researches on the Carrier Indians of British Columbia and investigated a burial site on an island off the coast of Alaska. He devoted the rest of the year to editorial and organizational work on the proposed Handbook of South American Indians. Dr. H. B. Collins, Jr., continued his study of collections from Eskimo sites in the vicinity of Bering Strait. Dr. W. N. Fenton conducted field

work among the Senecas of Allegany Reservation, N. Y., and carried forward a number of other investigations dealing with Iroquois problems. Miss Frances Densmore, a collaborator of the Bureau, continued her study of Indian music, collecting additional songs, transcribing these and songs previously recorded, and preparing material for publication. The Bureau published its annual report and three bulletins. The library accessioned 378 items and relabeled and reshelved over 5,000 books.

International Exchange Service.—The Exchange Service acts as the official United States agency for the interchange of parliamentary, governmental, and scientific publications between this country and the rest of the world. During the past year the Service handled 576,282 packages of such publications, with a total weight of 388,649 pounds. Naturally, the last 2 years have shown a marked falling off in the number of packages passing through the Exchange Service because of war conditions in large parts of the world. The material that cannot now be shipped abroad will be stored at the Institution until the end of hostilities. Transmission of shipments to and from Great Britain and to Latin America has been practicaly uninterrupted, and some material has been forwarded to Spain and Portugal, although irregularly. Five consignments of exchanges have been lost through war activities.

National Zoological Park.—The W. P. A. project which has been of such great assistance to the Park in the past few years was terminated on August 6, 1940, so that few improvements could be undertaken during the year. The four new waterfowl ponds were completed and birds transferred to them at the beginning of the year. The new restaurant constructed by the P. W. A. was completed in the fall of 1940 and was opened to the public in March 1941. Visitors for the year totaled 2,430,300, including 48,050 representing school or other groups from 20 States and the District of Columbia. The Smithsonian-Firestone Expedition to Liberia for the purpose of collecting live animals for the Zoo returned to this country in August 1940. The animals brought back numbered nearly 200, representing 61 species of mammals, birds, and other forms, several of them being new to the history of the collection. The usual large number of gifts was received during the year, and 70 mammals, 49 birds, and 14 reptiles were born or hatched in the Park. The total number of animals in the collection at the close of the year was 2,380, representing 730 different species. The chief need of the Zoo is for three new buildings: one for antelope, deer, wild hogs, and kangaroos; one for monkeys; and the third for carnivores.

Astrophysical Observatory.—At Washington the work of the staff was devoted largely to completing for publication the immense table

of daily solar-constant observations at the three field stations at Montezuma, Table Mountain, and Mount St. Katherine from 1923 to 1939. The rest of the text for volume 6 of the Annals of the Observatory was also nearly completed, and the whole is expected to be ready for the printer before January 1942. During preparation of a paper on "An Important Weather Element Hitherto Generally Disregarded," Dr. Abbot noted that the solar variation is several times greater in percentage for blue-violet rays than for total radiation. This led him to consider whether the sun's variation might not be more effectively followed by observations limited to the blue-violet region of the spectrum. He finally devised a method of thus restricting the observations, which was introduced near the close of the year at the three field observing stations. There is great hope that the new method will yield more reliable daily indications of the solar variations. Dr. H. Arctowski continued his meteorological investigations relating to the effects of solar variation on atmospheric barometric pressure and temperature and completed a manuscript incorporating the results of this study which will be published during the coming year. Daily determinations of the solar constant of radiation were made at the three field stations whenever conditions permitted. A new concrete dwelling house for the observers was erected at the Montezuma station.

Division of Radiation and Organisms.—The Division continued its program of research on the relation of radiation to various phases of plant growth. In continuing the project dealing with the genesis of chlorophyll and the beginning of photosynthesis, a large amount of information was obtained on the respiration of etiolated barley seedlings. This material is important because of its bearing upon photosynthesis as measured by the gaseous exchange method. It appears that conditions of carbon dioxide storage or depletion develop in the plant tissue depending upon the concentration of this gas surrounding the plants. In subsequent periods, when the respiration is measured there is an increase or decrease in the rate of CO_2 excretion (i. e., in the apparent rate of respiration) until a state of equilibrium with the new environment is attained. Considerable time was spent in improving the performance of the spectrograph used in measuring carbon dioxide for very short periods, and the new features developed have greatly improved the speed-sensitivity and stability of the apparatus. Further study was made of the spectral effectiveness of radiation for the growth inhibition of the oats mesocotyl, and a comparative study was undertaken of some other species of grasses. A paper resulting from experiments in the ultraviolet irradiation of algae showed that algae exposed four times

to stimulative amounts of certain wave lengths of the ultraviolet exhibited 4 to 4.8 times the growth rate (expressed as number of cells) of the control cultures. The influence of culture conditions on the photosynthetic behavior of the alga *Chlorella pyrenoidosa* was investigated. The growth cycle of this organism was studied in relation to light intensity, carbon dioxide concentration, and the composition of the nutrient solution. A number of papers were presented by members of the staff before meetings of scientific bodies, and six publications resulting from the work of the Division were issued during the year.

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust, Congress determined that the Federal Government was without authority to administer the trust directly, and, therefore, constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

Changes in the personnel of the Board of Regents during the fiscal year included the succession of Vice President Henry A. Wallace to the membership held by former Vice President John N. Garner, effective January 20, 1941, the Vice President being by law a regent ex officio, and the appointment by the Speaker of the House of Representatives on January 22, 1941, of Representative Foster Stearns, of New Hampshire, to succeed Representative Charles L. Gifford, who had resigned his membership as a regent.

The roll of regents at the close of the fiscal year was as follows: Charles Evans Hughes, Chief Justice of the United States, Chancellor; Henry A. Wallace, Vice President of the United States; members from the Senate—Charles L. McNary, Alben W. Barkley, Bennett Champ Clark; members from the House of Representatives—Clarence Cannon, William P. Cole, Jr., Foster Stearns; citizen members—Frederic A. Delano, Washington, D. C.; Roland S. Morris, Pennsylvania; Harvey N. Davis, New Jersey; Arthur H. Compton, Illinois; and Vannevar Bush, Washington, D. C.

Proceedings.—The annual meeting of the Board of Regents was held on January 17, 1941. The regents present were Chief Justice

Charles Evans Hughes, Chancellor; Senator Bennett Champ Clark; Representatives Charles L. Gifford and Clarence Cannon; citizen regents Frederic A. Delano, Roland S. Morris, Harvey N. Davis, and Vannevar Bush; and the Secretary, Dr. Charles G. Abbot.

The meeting was held in the Smithsonian main hall, which had recently been newly decorated and equipped with illustrative exhibits giving a comprehensive view of all Smithsonian activities. The new exhibits were viewed with approval by the regents.

The Board received and accepted the Secretary's annual report covering the year's activities of the parent institution and the several Government branches. The Board also received and accepted the report by Mr. Delano, of the executive committee, covering financial statistics of the Institution; and the annual report of the Smithsonian Art Commission.

The Secretary informed the regents of the death of Mrs. Mary Vaux Walcott on August 22, 1940, and of her designation of the Smithsonian Institution as residuary legatee, the bequest, when received, to be made a part of the Charles D. and Mary Vaux Walcott Research Fund set up by the former Secretary. Appropriate resolutions were adopted by the Board.

In his usual special report the Secretary mentioned briefly the more important activities carried on by the Institution and its branches during the year.

FINANCES

A statement on finances will be found in the report of the Executive Committee of the Board of Regents, page 130.

MATTERS OF GENERAL INTEREST

SMITHSONIAN RADIO PROGRAM

The Smithsonian educational radio program, "The World is Yours," celebrated its fifth anniversary on the air on June 14, 1941. On that date a special program was prepared wherein extracts from specially successful previous broadcasts were woven together into a composite story to illustrate the way in which the various sciences are handled in this series. "The World is Yours," a series of weekly half-hour broadcasts in dramatized form on science, invention, history, exploration, and art, is put on the air over a Nation-wide network through the cooperation of the United States Office of Education and the National Broadcasting Co. The program subjects are selected by the Smithsonian editorial division and the scripts are written by a professional script writer, employed by the Institution, from material furnished by Smithsonian experts in the various fields.

The programs are produced in Radio City, New York, as an N. B. C. public service feature and go out over the N. B. C. red network.

That the popularity of the program has continued undiminished is shown by the fact that an official rating service has twice within the past 2 years placed "The World is Yours" at the top of all noncommercial programs on all networks. A recent rating of N. B. C. public service programs by percentage of station program directors selecting them placed "The World is Yours" sixth on the list, but most of the five rated above it were programs devoted to discussion of current events, which are naturally of greatest interest in these disturbed times.

The list of subjects covered by "The World is Yours" during the past fiscal year is as follows:[1]

	1940
Mexico, Land of Silver	July 7
John Deere's Steel Plow	July 14
Primitive Mariners	July 21
Is There Life on Other Planets?	July 28
Glaciers	Aug. 4
Our Island Universe	Aug. 11
From Liberian Jungle to Zoo	Aug. 18
Exploring Cliff Dwellings of the West	Aug. 25
Story of the Silver Screen	Sept. 1
The Fall of a Meteorite	Sept. 8
Nature's Migrants	Sept. 15
Reaching the Upper Air	Sept. 22
The World's Most Important Chemical Reaction	Sept. 29
Prospecting for Black Gold	Oct. 6
Discovering the Source of the Mississippi	Oct. 13
With the Clipper Ships to China	Oct. 20
An Indian League of Nations	Nov. 3
Independence Hall	Nov. 10
New Wonders of Chemistry	Nov. 17
The Land Makes History	Nov. 30
500 Years of Printing	Dec. 7
Pueblo Indians on the Plains	Dec. 14
The Story of the Parachute	Dec. 21
Forward with Science	Dec. 28
	1941
The Dinosaur National Monument and Its Fossils	Jan. 4
Behind the Scenes at the Smithsonian	Jan. 11
Aircraft Engines	Jan. 18
The Electron Microscope	Jan. 25
The Army Medal of Honor	Feb. 1
The Story of Vitamins	Feb. 8
Treaties with the Indians	Feb. 15
Disseminating Knowledge Throughout the Earth	Feb. 22

[1] No broadcasts were given on October 27 and November 24, 1940, and April 26, 1941, because of important addresses or other commitments by N. B. C. for the usual period of "The World is Yours."

	1941
Army and Navy Uniforms	Mar. 1
The Nation's New Art Gallery	Mar. 8
300 Years of Chemistry	Mar. 15
Coins of America	Mar. 22
Fifty Centuries of Silk	Mar. 29
Champlain in New England	Apr. 5
Smithsonian Field Expeditions	Apr. 12
Brazil, Land of Gems	Apr. 19
Ancient Crete	May 3
Birds of the Sea	May 10
The Saga of the Norsemen	May 17
Oliver Evans—Early American Engineer	May 24
Exploring Alaska	May 31
Platinum	June 7
Five Years of The World Is Yours (anniversary program)	June 14
Calendars of all Times	June 21
How Plants Grow	June 28

The Institution was unable, because of lack of funds to employ additional personnel, to resume publication of the supplementary articles, or "listener-aids," which up to June 30, 1940, contributed greatly to the educational value of "The World is Yours" programs. It is hoped that a way will be found to reestablish this part of the project during the coming year.

WALTER RATHBONE BACON SCHOLARSHIP

A bequest made to the Institution in 1919 in the will of Mrs. Virginia Purdy Bacon, of New York, provided for the establishment of a traveling scholarship, to be known as the Walter Rathbone Bacon scholarship for the study of the fauna of countries other than the United States of America.

For the past 2 years the Bacon scholarship has been held by Dr. Hobart M. Smith, whose purpose was the accumulation of specimens of reptiles and amphibians from Mexico, on the basis of which a herpetology of Mexico might be compiled and the biotic provinces of the country more accurately defined.

During the year 1940–41, the some 20,500 specimens of reptiles and amphibians obtained during the 2 preceding years were sorted and a portion studied and entered in the permanent collections of the National Museum. The collection requires study that could not be completed within the year, and as a result certain groups must be reserved for study at a later date.

A total of 1,421 specimens of snakes was obtained, representing 170 species and subspecies, of which 23 appear unnamed. These comprise about half the species known from Mexico. Nineteen specimens

of three species of crocodilians, all that are known from Mexico, were obtained. The study of these groups has been completed.

Not all the lizards have been studied yet. Completed genera number 22, comprising 4,547 specimens of 116 species and subspecies. Eleven are unnamed. Six lizard genera remain to be studied.

The amphibians are not completed. A preliminary sorting, however, reveals some 5,173 frogs and toads, of about 110 species; 5,064 specimens of approximately 40 species of salamanders; and 6 specimens of one species of caecilian. Most of these are being studied by Dr. E. H. Taylor.

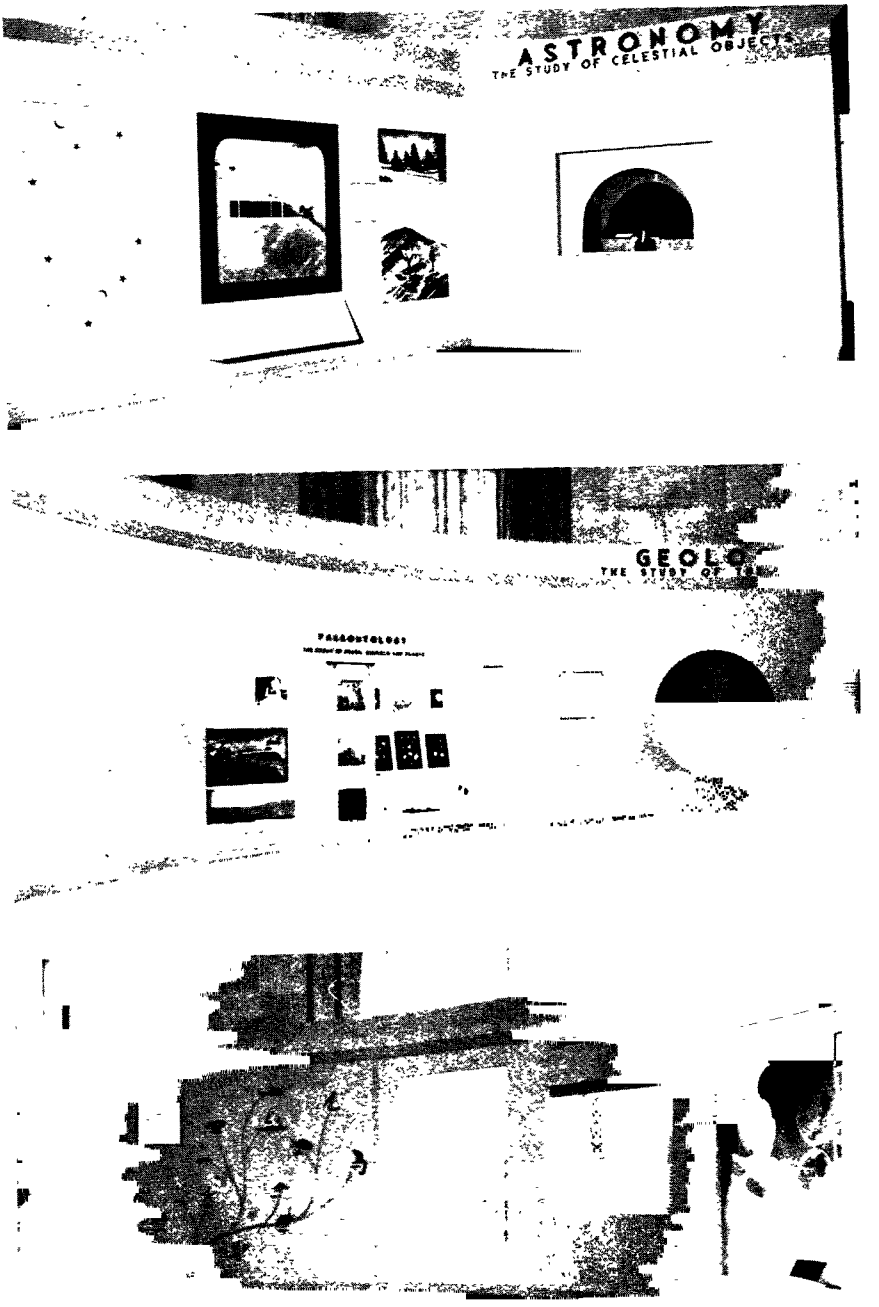
The turtles have been turned over to Dr. Leonhard Stejneger for study.

While most of the data pertaining to this collection are reserved for a future paper, descriptions of new species and surveys of certain genera have been prepared for preliminary publication. Seven such papers have been issued during the present year.

SMITHSONIAN MAIN HALL EXHIBIT

In my last two annual reports I have spoken of the project of installing in the main hall of the Smithsonian Building a new type of exhibit intended to serve as a visual index to all Smithsonian activities. During the 95 years since the founding of the Institution, its activities have so expanded in scope and the buildings it occupies have so increased in number that it has been impossible for visitors to get an adequate idea of what the Smithsonian is and what it does. The project was brought to completion during the year, and the new exhibit was formally opened to the public on Monday, January 20, 1941. The Board of Regents of the Institution had a preview of the exhibit on January 17, when their annual meeting was held in the main hall.

As stated previously, the entire project has been handled by a committee consisting of Messrs. C. W. Mitman, chairman, W. F. Foshag, Herbert Friedmann, F. M. Setzler, and W. P. True, all of the Institution's staff. The great hall of the Smithsonian building, some 150 feet long by 50 feet wide, was first completely redecorated according to the committee's recommendation. Then special backgrounds for the exhibits were designed and constructed to form eight separate alcoves and four quadrants, the central aisle being left clear for free circulation of visitors. The eight alcoves present graphically the work of the Institution in astronomy, geology, biology, radiation and organisms, physical anthropology, cultural anthropology, engineering and industries, and art. The four quadrants, facing the central area of the hall, contain exhibits on the scope of the Institution's work, the National Zoological Park, history, and the organization and branches of the Institution.



NEW "INDEX EXHIBIT" AT THE SMITHSONIAN INSTITUTION.

Upper, part of the astronomy exhibit
Center, part of the geology exhibit.
Lower, part of the biology exhibit.



NEW "INDEX EXHIBIT" AT THE SMITHSONIAN INSTITUTION.

Upper, part of the radiation and organisms exhibit.
Center, part of the cultural anthropology exhibit.
Lower, part of the engineering and industries exhibit.

The plan of each of the eight alcoves is the same (see pls. 1 and 2. The name of the subject treated is stated at the top, followed by a brief definition. Below this, a central theme consisting of a diorama, working model, or other device illustrates strikingly the significance of the particular subject. Flanking this on either side of the alcove are exhibits to show as simply as possible what the Smithsonian Institution does in each field. The number of objects shown is kept small, labels are made as short and simple as possible, and the whole attempt is to make the exhibits interesting and popular and at the same time instructive.

A valuable adjunct of the new exhibit is a separate room opening off the main hall in which are exemplified the Institution's methods of diffusing knowledge. One feature is a complete bound set of all Smithsonian publications from 1846 to the present. The books occupy 138 running feet of shelf space. Placards describe these publications, as well as the Institution's educational radio programs, press releases, International Exchange Service, exhibits, lectures, correspondence, and library. An important feature of this room is an information desk where visitors may obtain accurate information on special phases of the Institution's work or exhibits.

Visitors to this new exhibit for the last 5 months of the fiscal year—from February 1 through June 30, 1941—totaled 191,699. Comparable figures for the preceding year are not available because the building was closed at that time in preparation for the new exhibit, but the total number of visitors for the corresponding months of 1939 was 144,372. The present year therefore shows an increase of 47,327 visitors, or 32 percent, over 1939.

The committee in charge of the project has been kept in existence to supervise maintenance of the exhibits and to incorporate changes from time to time, for the intention is to keep the whole exhibit alive and up to date. Wide and favorable notice has been given the exhibit by journals and newspapers.

TENTH ARTHUR LECTURE

The late James Arthur, of New York, in 1931 bequeathed to the Smithsonian Institution a sum of money, part of the income from which should be used for an annual lecture on the sun.

The tenth annual Arthur lecture was given by Brian O'Brien, professor of physiological optics at the University of Rochester, under the title "Biological Effects of Solar Radiation on Higher Animals and Man," in the auditorium of the National Museum on the evening of February 25, 1941. The lecture will be published in a forthcoming Smithsonian Report.

The nine previous Arthur lectures have been as follows:

1. The Composition of the Sun, by Henry Norris Russell, professor of astronomy at Princeton University. January 27, 1932.
2. Gravitation in the Solar System, by Ernest William Brown, professor of mathematics at Yale University. January 25, 1933.
3. How the Sun Warms the Earth, by Charles G. Abbott, Secretary of the Smithsonian Institution. February 26, 1934.
4. The Sun's Place among the Stars, by Walter S. Adams, director of the Mount Wilson Observatory. December 18, 1934.
5. Sun Rays and Plant Life, by Earl S. Johnston, assistant director of the Division of Radiation and Organisms, Smithsonian Institution. February 25, 1936.
6. Discoveries from Eclipse Expeditions, by Samuel Alfred Mitchell, director of the Leander McCormick Observatory, University of Virginia. February 9, 1937.
7. The Sun and the Atmosphere, by Harlan True Stetson, research associate, Massachusetts Institute of Technology. February 24, 1938.
8. Sun Worship, by Herbert J. Spinden, curator of American Indian Art and Primitive Cultures, Brooklyn Museums. February 21, 1939.
9. Solar Prominences in Motion, by Robert R. McMath, director of the McMath-Hulbert Observatory of the University of Michigan. January 16, 1940.

BEQUESTS

Mary Vaux Walcott bequest.—Mary Vaux Walcott, widow of the late Charles D. Walcott, former Secretary of the Smithsonian Institution, died August 22, 1940. Mrs. Walcott had for many years been deeply interested in the Institution and its work, and during the years 1925 to 1930 her beautiful water-color sketches of North American wild flowers were published in five sumptuous volumes under the auspices of the Institution. During her lifetime Mrs. Walcott manifested her interest by numerous valuable gifts, both in the form of specimens and of money for specific purposes connected with Smithsonian researches. In her will she named the Institution residuary legatee, the relevant portions of that document reading in part as follows:

> I give, devise and bequeath all the rest, residue and remainder of my estate * * * to the Smithsonian Institution * * * in memory of my beloved husband, Charles D. Walcott, to be added to and form a part of the Charles D. and Mary Vaux Walcott Reasearch Fund, established by my husband in his lifetime, with the express stipulation, however, that the restriction as to the use of the income of said fund shall not apply to the income from this devise and bequest.

At the annual meeting of the Board of Regents on January 17, 1941, the following resolutions were adopted:

> *Resolved*, That the Board of Regents of the Smithsonian Institution learns with profound sorrow of the death on August 22, 1940, of Mrs. Mary Vaux Walcott, widow of its late Secretary.

The noble character of Mrs. Walcott, her great skill and zeal in depicting wild flowers, her personal researches in glacial geology, her deep interest in the paleontologic researches of Dr. Walcott, and her many gifts, over a long period, to the Smithsonian Institution are highly appreciated.

Resolved, That this Board learns with profound gratitude of Mrs. Walcott's large bequest to the endowment of the Smithsonian Institution in memory of her late husband.

Further resolved, That these resolutions be spread on the minutes of this meeting and that a copy of them be sent to Mrs. Walcott's executors.

The amount of Mrs. Walcott's bequest was slightly over $400,000. At the close of the fiscal year, the estate had not been settled.

Julia D. Strong bequest.—In the final accounting of the will of Julia D. Strong, of Washington, D. C., who died April 12, 1936, the National Collection of Fine Arts of the Smithsonian Institution, as alternate beneficiary, received the sum of $10,000. No stipulations as to the use of the fund were stated in the will.

Florence Brevoort Eickemeyer bequest.—The will of the late Florence Brevoort Eickemeyer, of Yonkers, N. Y., contained the following provision:

I give and bequeath to the Smithsonian Institution * * * the sum of $10,000 * * * to use or apply the income thereof, or as much thereof as may be necessary, in or about the exhibition, preservation and care of my late husband Rudolf Eickemeyer Jr.'s photographic works and collection, the residue or surplus of such income, if any, to be applied to the uses and purposes of the Section of Photography established or maintained by said Institution. My late husband, Rudolf Eickemeyer, Jr., in and by his last will and testament and codicil thereto, intended to provide a fund for the exhibition and care of his photographic works and collection, bequeathed thereby to said Smithsonian Institution, and his estate being sufficient to provide such fund, I do hereby make the above bequest to carry out my late husband's purpose in that regard.

The money thus bequeathed had not been received at the close of the year.

Alfred Mussinan bequest.—The Smithsonian Institution is named as a residuary legatee of the estate of the late Alfred Mussinan, of Sumter County, Fla. His will divides his estate into two equal parts, and upon the death of certain legatees named in the will, the Institution is to receive five-eighths of the principal sum of one-half of the estate, "the income therefrom to be used by said institution for the increase and diffusion of knowledge among men." The amount of Mr. Mussinan's estate was estimated by the executor in May 1941 to be approximately $30,000, in addition to real estate, stocks, and bonds in Germany which it was impossible to evaluate.

EXPLORATIONS AND FIELD WORK

In the furtherance of its investigations in many branches of science, the Smithsonian sent out or cooperated in 19 expeditions, which

worked not only in many States in the United States, but also in a number of foreign lands as well.

Paleontological work was carried on by Dr. Charles E. Resser in investigations of ancient Cambrian rocks; by Dr. C. Lewis Gazin in Utah and Woming, resulting in the discovery of an almost complete fossil skeleton of the primitive mammal known as an uintathere; and by Dr. G. Arthur Cooper in Texas and Tennessee where an abundance of fossil material, much needed in the Museum's study collection, was obtained.

Dr. Willian M. Mann, Director of the National Zoological Park, and Mrs. Mann went to Liberia on an expedition financed by the Firestone Tire & Rubber Co., and brought back an assortment of live animals for the Zoo, including a 400-pound hippopotamus, and some 3,000 preserved specimens for the Museum. Dr. Alexander Wetmore spent a month in Costa Rica studying the birds of that region. W. L. Brown collected material in the Canadian Rockies for backgrounds for the Rocky Mountain goat and sheep groups exhibited in the Museum. Dr. Hobart M. Smith, holder of the Walter Rathbone Bacon scholarship, assisted by Mrs. Smith, continued his study of the reptiles and amphibians of Mexico. Dr. Waldo L. Schmitt participated in the biological investigations of the king crab of Alaska, initiated by the United States Fish and Wildlife Service. Capt. Robert A. Bartlett conducted another expedition to Greenland, and Mr. and Mrs. Russell Hawkins, Jr., visited the Gulf of California, both to collect marine material. Austin H. Clark carried on his observations of the butterflies of Virginia. Mrs. Agnes Chase made an extensive study of the grasses of Venezuela, bringing back large collections including 11 species previously unknown.

Dr. T. D. Stewart spent several weeks at the historic Indian village site on Potomac Creek in Virginia known as Patawomeke, examining an ossuary that was discovered during the previous field season. Dr. Waldo R. Wedel conducted archeological investigations in central Kansas in an effort to locate Coronado's "Province of Quivira." David I. Bushnell, Jr., made several trips to the vicinity of the Peaks of Otter in search of tangible evidence of early man in Virginia. Dr. Frank H. H. Roberts, Jr., obtained further information on Folsom man, one of the earliest known inhabitants of America, from excavations at the Lindenmeier site in Colorado. Dr. Julian H. Steward visited British Columbia to record culture changes among the Carrier Indians; Dr. John P. Harrington made a comparative study of the northwestern Indians in Alaska and the southwestern Indians in New Mexico; and Dr. William N. Fenton collected data among the Seneca in New York State on Iroquois masks and ritualism.

PUBLICATIONS

The publications of the Smithsonian Institution constitute its chief means of carrying out one of its primary functions, the "diffusion of knowledge." From its private funds, the Institution issues the Smithsonian Miscellaneous Collections, a series containing all the scientific papers published by the Institution proper; from Government funds are issued the Smithsonian Annual Report (with general appendix reviewing progress in science), the Bulletins and Proceedings of the National Museum, the Contributions from the National Herbarium, the Bulletins of the Bureau of American Ethnology, the Annals of the Astrophysical Observatory, and Catalogs of the National Collection of Fine Arts. The Freer Gallery of Art pamphlets and the series, Oriental Studies, are supported by Freer Gallery funds.

All publications of the Institution are issued through the editorial division, which comprises the central office where publications of the Institution proper are handled, the office of the editor of the National Museum, and that of the editor of the Bureau of American Ethnology. The editorial division also directs the Institution's informational activities and its radio work.

The year's publications totaled 78, of which 48 were issued by the Institution proper, 25 by the National Museum, 3 by the Bureau of American Ethnology, 1 by the National Collection of Fine Arts, and 1 by the Freer Gallery of Art. Information as to titles, authors, and other details concerning these publications will be found in the report of the chief of the editorial division, appendix 11. The total number of publications distributed was 125,837.

Among the outstanding publications of the year may be mentioned a paper by the Secretary entitled "An Important Weather Element Hitherto Generally Disregarded," wherein are summarized evidences of the dependence of our weather on the variations of solar radiation; a revised edition of Assistant Secretary Alexander Wetmore's "A Systematic Classification for the Birds of the World"; another volume in the series of life histories of North American birds by Arthur Cleveland Bent entitled "Life Histories of North American Cuckoos, Goatsuckers, Hummingbirds, and Their Allies"; a paper dealing with the very interesting Chicora (Butler County, Pa.) meteorite, by F. W. Preston, E. P. Henderson, and James R. Randolph; and part 2 of the monograph entitled "Archeological Remains in the Whitewater District, Eastern Arizona," by Frank H. H. Roberts, Jr.

LIBRARY

The year's accessions to the Smithsonian library totaled 6,839 volumes, pamphlets, and charts, bringing the holdings at the end of

the year to 894,655 items. As usual, many gifts were received, among the largest of which were a collection of 942 scientific books and journals belonging to the late Frederick E. Fowle of the Smithsonian staff and presented by his widow; 622 publications from the Geophysical Laboratory of the Carnegie Institution of Washington; and 612 publications from the American Association for the Advancement of Science. Again during the past year the library's exchange work was carried on with great difficulty because of war conditions abroad. Most of the publications that failed to come were European and Asiatic. Some of these are being held by the issuing agencies for transmission after the wars are over, others have delayed publication, but a few have been discontinued. The library staff cataloged 6,693 volumes, pamphlets, and charts; prepared and filed 40,238 catalog and shelf-list cards; made 22,311 periodical entries; loaned 10,990 publication to members of the Smithsonian staff; and conducted an interlibrary loan service with 45 libraries outside the Smithsonian system. Other activities included work on the union catalog; a large amount of bibliographic assistance to members of the Smithsonian staff and others; and checking of the serial holdings in connection with the forthcoming second edition of the Union List of Serials. The funds allotted to the library permitted it to bind 958 volumes—only one-half of those completed for binding during the year. The most urgent need, therefore, is for more adequate funds for binding in order to prevent loss of parts of volumes that may be very difficult, if not impossible, to replace.

Respectfully submitted.

C. G. Abbot, *Secretary.*

APPENDIX 1

REPORT ON THE UNITED STATES NATIONAL MUSEUM

SIR: I have the honor to submit the following report on the condition and operation of the United States National Museum for the fiscal year ended June 30, 1941.

Funds provided for the maintenance and operation of the National Museum for the year totaled $818,305, which was $6,580 more than for the previous year. The amount was reduced $6,500, however, by reason of a compulsory administrative reserve.

COLLECTIONS

Building up of the great collections of the Museum continued, and a total of 1,518 separate accessions, aggregating 326,686 individual specimens, was received during the year. Although this was about 400 fewer separate accessions than last year, the individual specimens increased by 114,000. Distribution of these additions among the five departments was as follows: Anthropology, 4,064; biology, 262,521; geology, 55,818; engineering and industries, 2,688; and history, 1,595. For the most part these acquisitions were gifts from individuals or represented expeditions sponsored by the Smithsonian Institution. All are listed in detail in the full report on the Museum, published as a separate document, but the more important are summarized below. The total number of catalog entries in all departments is now nearly 17½ million.

Anthropology.—Important archeological material included a collection of Paleolithic, Neolithic, and Bronze Age implements and ornaments from Java; over 700 stone artifacts from western New York; about 450 specimens from an Indian village site in Page County, Va.; and nearly 1,000 potsherds and shell implements from burial mounds near Belle Glade, Fla. In ethnology, many objects were received representing the cultures of the Navaho; Alaskan Indians and Eskimos; Plains, Pueblo, and Southwestern tribes; the Iroquois; and others. Collections from peoples outside the Americas included specimens from Malayan tribes of the Philippines, from the Grebo of Liberia, and from the natives of Bali. Twenty-nine ceramic specimens, 30 musical instruments, and 47 pieces of period art and textiles were added. In the division of physical anthropology, skeletal remains from Peru and from southeastern Alaska and a

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reconstruction of the newly found remains of the fourth *Pithecanthropus* were the principal acquisitions.

Biology.—Biological specimens, many of great scientific value, totaled 262,521, a considerable increase over last year, although these came in fewer individual accessions. The most important mammalian accession was a complete skull and both sets of baleen of an adult humpback whale (*Megaptera novae-angliae*) and a fetal whalebone whale skull from the North Pacific. Other mammals received included 74 specimens from Liberia; 102 from South Carolina; 85 cavernicolous bats; other bats from Mexico, the Virgin Islands, and Puerto Rico; 2 fetuses of humpback whales; a baby walrus skeleton; and other specimens from Indo-China, Ecuador, Korea, Costa Rica, Bolivia, and Brazil. Of nearly 100 mammals received from the National Zoological Park, the most important was a gayal (*Bos frontalis*).

Large representations of birds came from Indo-China, Costa Rica, Brazil, Antarctica, Mexico, and Manchukuo. Field work of the Museum in South Carolina yielded 1,205 bird skins for the study collections.

Incorporated in the collections during the year were 4,201 Mexican reptiles received from the Smithsonian Institution as the major part of the collections made by Dr. Hobart M. Smith, under the Walter Rathbone Bacon scholarship, among them being types of many new forms and representatives of species hitherto not contained in the Museum. The second installment of Dr. W. M. Mann's reptilian and amphibian collections in Liberia consisted of 472 specimens, representing several new forms and much valuable comparative material from territory hitherto little known.

Nearly 2,000 Liberian fishes also resulted from the Smithsonian-Firestone Expedition headed by Dr. Mann, in addition to those accessioned last year. Among other ichthyological specimens received were 900 fishes from Texas and the Gulf of Mexico, 420 from Alaska, and 60 sharks from Florida and Texas.

The most important accession in insects was the Nevermann collection of Costa Rican Coleoptera, comprising about 33,000 specimens and including much type material. Other important entomological material came in many miscellaneous lots, the largest being 64,000 insect specimens transferred from the Bureau of Entomology and Plant Quarantine. A collection of nearly 3,000 beetles from Panama was donated by Assistant Curator Richard E. Blackwelder, who collected them several years ago.

About 500 marine invertebrates from the west coast of Greenland came as a result of the Bartlett Greenland Expedition of 1940. Through Curator Waldo L. Schmitt there was accessioned a large

collection of marine invertebrates taken in the course of the Alaska king crab investigations of the Fish and Wildlife Service. From this same Service there was transferred a lot of nemertean worms collected by the *Albatross* and *Fish Hawk*. Outstanding also was a large collection of mollusks, echinoderms, crustaceans, miscellaneous invertebrates, and 182 bottom samples obtained by Russell Hawkins, Jr., on 1939 and 1940 cruises along the west coast of Baja California and in the Gulf of California. Over 3,000 selected molluscan specimens were obtained by purchase through the Frances Lea Chamberlain Fund. A remarkably fine collection of over 3,000 Samoan shells was contributed, as well as 1,000 land and fresh-water shells from Texas. Several interesting lots of echinoderms were added, chiefly from the Antarctic region, from Greenland, and from the Abrolhos Islands, Western Australia.

About 25,000 plants from many sources were added to the collections of the National Herbarium.

Geology.—Many choice minerals and gems were acquired through the Canfield, Roebling, and Chamberlain funds of the Smithsonian Institution. The finest mineral specimen is an 1,800-carat aquamarine crystal from Agua Preta, Brazil, showing the rare berylloid form. The extensive Diaz collection of Mexican cassiterites and valuable sets of minerals from Bolivia also are noteworthy. Gems added included a brilliant cut purple enclase of 46 carats from Ceylon, and a greenish-yellow 9-carat enclase from Brazil. Another important acquisition consisted of 620 Brazilian gem stones transferred from the United States Treasury Department. The outstanding addition to the meteorite series was the Sardis, Ga., specimen, an altered iron, weighing 1,760 pounds, the fifth largest single meteorite ever found in the United States. Four meteoritic falls, all American, were represented in specimens presented by Dr. Stuart H. Perry, associate in mineralogy. A valuable series of tin ores resulted from Curator W. F. Foshag's studies for defense purposes of the tin resources of Mexico.

Field work by members of the staff yielded the bulk of the invertebrate fossils accessioned: About 8,000 Cambrian brachiopods and trilobites from the Rocky Mountain region, Missouri, and the Appalachian Valley; 20,000 post-Cambrian specimens from west Tennessee and Texas; and 15,000 Devonian fossils from the various counties in the geologically classic Lower Peninsula of Michigan. Much valuable type material was contained in other miscellaneous accessions, mostly gifts, including Upper Cambrian invertebrates from Texas and southeastern Missouri, Ordovician Bryozoa from Oklahoma, Upper Triassic ammonites from Nevada, and type fossils from the Kaibab formation of the Grand Canyon. Important

lots of Foraminifera came from such widely separated regions as Mexico, Peru, New Zealand, and Arabia. Casts of 256 type specimens of the fossil shell *Turritella*, from the Tertiary rocks of the Pacific coast, comprised an outstanding addition to the Cenozoic collections.

As a result of paleontological field work in central Utah several articulated Upper Cretaceous lizard skeletons (*Polyglyphanodon*) and fragmentary mammalian jaws and teeth from the Paleocene were received, in addition to 149 lots of vertebrate fossils collected from the Bridger Eocene of southwestern Wyoming. Also worthy of special mention among the new vertebrate material are the greater part of the skeleton of the primitive mammal *Uintatherium*, a partial skeleton of a *Palaeosyops*, and a perfect skull and jaws of the dog-like *Thinocyon velox*. Parts of several fossil whales and porpoises, from the Miocene Calvert formation of the Chesapeake Bay country, were acquired.

Engineering and industries.—To the section of transportation and civil engineering came an operating exhibit of the Westinghouse air brake, and three fine scale models, the Polish motorship *Pilsudski*, the Rolls Royce automobile *Silver Ghost*, and the diesel-engined trawler *Storm*.

A unique accession in the section of aeronautics, received as a transfer from the Navy Department, was a fighter airplane known as the Curtiss Sparrowhawk, a type developed in 1931–35 as an auxiliary fighter to the dirigibles *Akron* and *Macon*. Several interesting airplane models were received: The original model of a steam-engined bombing helicopter designed in Civil War times and scale models of the Columbia monoplane (1910), the triplane bomber (1918), the U. S. Army pursuit type P–35, the U. S. Army trainer type BT–8, and the amphibian SEV–3N.

In mechanical engineering the outstanding accession was an exceptional operating model made by Howell M. Winslow of a Reynolds-Corliss steam engine of about 1900. The section of electrical engineering and communication received three original Plante storage battery plates and two replicas of the posted plate batteries made by T. A. Willard in 1881; also the tone arm of a modern photoelectric phonograph.

One of the most spectacular acquisitions in recent years is the 93-dial display clock made by Louis Zimmer, of Lier, Belgium, for the Brussels World's Fair in 1935. It is 14 feet high, tells the standard time of many places around the world, the tides in various parts, and a great variety of calendar and astronomical events. The section of woods and wood technology received the first letter file made to handle correspondence unfolded and vertical. An important and generous gift to the division of graphic arts was a collection

of 200 Currier and Ives prints from a donor, who in addition lent 183 others. There came also as a loan the original camera believed to have been used around 1836 by Dr. John W. Draper, the eminent American chemist and physiologist, while a member of the faculty of Hampden-Sydney College, Richmond, Va.

History.—Nearly 1,600 objects of historic and antiquarian interest were accessioned, including busts, costumes, or mementos of such outstanding Americans as Abraham Lincoln, Mrs. Andrew Jackson Donelson, Col. Samuel Simpson, William Jennings Bryan, Henry B. F. Macfarland, and Brig. Gen. Caleb Cushing. The numismatic collection was increased by 176 coins and medals, including a series of United States bronze, nickel, and silver coins struck at the Denver, Philadelphia, and San Francisco mints in 1914; and the philatelic collection by 1,310 stamps and other items.

EXPLORATIONS AND FIELD WORK

Field exploration by the Museum's experienced staff and its collaborators continues as one of the most important sources for additions of new materials in the broad fields of anthropology, biology, and geology. As in previous years this work was financed in the main through funds provided by the Smithsonian Institution or through interested friends of the Institution. The specimens obtained have filled many gaps in the Museum's series.

Anthropology.—During August and September, 1940, Dr. T. Dale Stewart, associate curator of physical anthropology, continued excavations at the historic Indian village site known as Patawomeke on Potomac Creek, in Stafford County, Va., completely exploring the ossuary discovered last year. The work this season yielded a number of facts that verify or supplement the meager historical records pertaining to the burial ceremonies of the Virginia tidewater Indians. Of the approximately 100 skeletons encountered in the ossuary, the majority had become disarticulated, or were disarticulated before burial. A few, however—approximately a dozen adults—were observed to be fully articulated. These were found on the bottom or along the sides of the pit and hence may have been the first bodies received into the grave. Moreover, all these articulated skeletons are possibly males and had their arms extended along their sides as do the bodies shown in John White's picture of a death house, which was drawn during his visit to Roanoke Island in 1585. Also, all these skeletons had their lower legs flexed unnaturally forward, which would have been a practicable way for shortening an extended body resting on its back. There is evidence, on the other hand, that the disarticulated skeletons were exposed

for a considerable period before burial; in several cases mud dauber nests were found in the skull or among the bundled bones. This finding indicates that the period in which these bodies were exposed in an open death house included at least one warm season.

On February 27, 1941, Dr. Stewart went to Peru in connection with the program sponsored by the State Department for cultural cooperation with other American republics. In Lima, through the kindness of Dr. Julio C. Tello, director of the Museum of Anthropology, Magdalena Vieja, he had the privilege of studying two documented series of human skeletal remains, one from Paracas and the other from Malena. These two series are interesting for comparison because that from Paracas is very early, whereas that from Malena is late coastal Inca. The Paracas people, although relatively ancient, were far from being primitive in the cultural sense. Their textiles are famous and among the finest produced anywhere. While in Lima Dr. Stewart visited many of the nearby ruins and ancient Indian sites. From these trips Dr. Stewart brought back a small collection of the more interesting skeletal remains to supplement earlier collections.

During the week of March 30 Dr. Stewart represented the Institution and the National Geographic Society at the Third Assembly of the Pan American Institute of Geography and History meeting in Lima. Following the Assembly he visited the Museo Arqueológico "Rafael Larco Herrera" at Chiclín, where, through the kindness of Sr. Rafael Larco Hoyle, he was able to study a documented series of Mochica and Cupianique skeletons. These remains are from the oldest cultural periods of the northern coast. From Chiclín Dr. Stewart went south to Mollendo, and thence by way of Arequipa to Cuzco. Here, besides visiting some of the famous ruins, he saw the fine collection of mummies and trephined skulls at the University of Cuzco and the Instituto Arqueológico.

Dr. Waldo R. Wedel, assistant curator in archeology, was in the field from June 1 to September 16, 1940, continuing the Institution's archeological survey of Kansas, begun in 1937. The 1940 explorations were carried on at several locations in Rice and Cowley Counties. Preliminary excavations show that the sites investigated mark villages inhabited by semisedentary, partly horticultural Indians who did not live in earth lodges. These people made pottery, wove basketry, had a wide variety of artifacts in stone, bone, horn, and shell, traded with the Pueblos on the Rio Grande for turquoise, pottery, and obsidian, and were in contact with white men. Fragments of glaze-paint pottery represent types made on the Rio Grande between 1525 and 1650, and bits of chain mail suggest a visit from some of the early Spanish explorers. It is tentatively

suggested that these remains, widespread in central and southern Kansas, may be of Wichita origin, and possibly represent some of the Quivira villages seen by Coronado, Humaña, Bonilla, and Oñate.

During the period from December 5 to 12, 1940, and again in May 1941, Dr. Wedel made a brief reconnaissance in the Holston River drainage near Saltville, Va. A number of extremely promising prehistoric village sites and two apparently affiliated burial caves were visited, and a local collection was studied. No excavations were undertaken. The cultural materials indicate some relationships with Middle Mississippi remains in Tennessee and adjacent States, but pending more extended studies their exact position culturally remains uncertain.

Walter W. Taylor, Jr., collaborator in anthropology, inaugurated archeological excavations in the state of Coahuila, Mexico. From January 1941 to the close of the fiscal year, Mr. Taylor surveyed a wide area in the various mountain valleys around Cuatro Ciénegas and excavated several small caves and one large cave. The principal purpose of this program was to determine the relationship between the prehistoric cave inhabitants in this northern section of Mexico and the inhabitants of similar sites in the Pecos River and Big Bend area of southwestern Texas. A superficial relationship seems evident from Mr. Taylor's field reports, but final conclusions must await a careful comparison of material in the Museum.

Biology.—During October and November Dr. Alexander Wetmore, Assistant Secretary of the Smithsonian Institution, visited Costa Rica as part of the program sponsored by the State Department for cultural cooperation with the other American republics. He was received with every courtesy as the guest of the Costa Rican Government, and in San José, the capital city, he worked at the National Museum and visited and conferred with officials in various branches as well as with scientists in other services. Following this, accompanied by Dr. Juvenal Valerio Rodríguez, director of the National Museum, and Carlos Aguilar in charge of the zoological collections in the Museum, he crossed by air to Liberia, the principal city of Guanacaste, the northwestern province of Costa Rica. From this base collections of birds were made in the surrounding country. Dr. Valerio returned to San José, while Mr. Aguilar remained for training in zoological field work. Guanacaste is devoted mainly to cattle raising, with small cultivation. Liberia lies on a slightly elevated plain east of the swampy lowlands bordering the Río Tempísque. For more than 2 weeks Dr. Wetmore and Mr. Aguilar were located at a great hacienda on the southern slopes of the Volcán Rincón de la Vieja where there was access to heavy rain forest on the mountain. Collections were obtained for the National Museum in San José as

well as for our Institution. The several hundred birds that have come to Washington as a result of this work add measurably to our series, as our earlier investigations of the birds of Costa Rica did not cover Guanacaste. On his return north at the end of November Dr. Wetmore had opportunity to spend a day in Habana, Cuba, where he was received by representatives of the Cuban Government and conferred with prominent scientists of the country.

From March to May, 1941, Dr. Wetmore visited Colombia in continuation of the program mentioned for closer personal contact and cooperation with scientists in our neighbor republics. In Bogotá he was received at the National University, where he worked particularly in the Instituto de Ciencias Naturales. He also conferred with scientists who had been in attendance at the Eighth American Scientific Congress in Washington the year previous, and visited scientific workers with whom the Smithsonian Institution has been in contact through correspondence for years. Following this, with M. A. Carriker, Jr., as assistant, and accompanied by Dr. F. Carlos Lehmann and his assistant from the Instituto de Ciencias Naturales and by Lt. Alejandro Rubiano as a representative of the Colombian Government, Dr. Wetmore set out from Santa Marta on a prolonged expedition through the Guajira Peninsula. The party traveled by truck to Riohacha stopping en route for work in extensive forest areas near the Río Ariguaní and its tributaries. Here in 8 days' time specimens of 100 distinct species of birds were obtained, an indication of the richness of the fauna. In Riohacha the party obtained another truck and here entered the Guajira proper. The peninsula in the main is an arid, desert country with extensive open savannas and broad stony plains, grown in places with heavy stands of mesquite and cacti that form veritable forests. In the eastern section there are low mountains with trails along their bases passable for heavy trucks except during the period of rains. On the highest range where the trade winds build a cloud cap with consequent more or less regular precipitation in contrast to the desert below, there is an island of tropical rain forest with the species usual to such an environment, here isolated by long distances from other similar areas. Dr. Lehmann and Lieutenant Rubiano completed their work with the party in April while the others continued to the forested region mentioned. On the return the middle of May it was necessary because of disrupted steamer schedules for Dr. Wetmore to cross by schooner from Puerto Estrella, in the Guajira, to the Island of Aruba. Here after a 2-day wait he obtained plane passage to Curaçao, and from there sailed for New York. A stop en route at La Guaira, Venezuela, gave opportunity to visit Caracas, where he was guest of honor at a luncheon given by W. H. Phelps

to a group of Venezuelan scientists, and had opportunity to visit the new Museo Nacional and the Sociedad Venezolana de Ciencias Naturales.

Mr. Carriker, whose expenses for this work in Colombia were carried by the W. L. Abbott fund of the Smithsonian Institution, continued in the field in the Guajira until late in June to finish the investigations. At the end of the fiscal year he was located in the Sierra Negra in the northern section of the Perijá Mountains, a region previously unknown to naturalists.

The collecting expeditions by W. M. Perrygo, scientific aid, to obtain much-needed material for the study of the vertebrate fauna of the Appalachian region, were continued with good results. Accompanied by John S. Webb, of the division of birds, he left for South Carolina on September 14, 1940, working first along the Catawba River and in the wooded regions of the Piedmont region and later collecting in the swamps along the Pee Dee River. The middle of October he continued southward to Allendale to complete work begun in the spring months along the Savannah River. Two weeks were spent in collecting along the Lynches River, a tributary of the Pee Dee, and the final stay centered around McClellanville for work in the salt marshes near the Cape Romaine Wildlife Sanctuary. The expedition returned December 3. This work also was financed through the W. L. Abbott fund of the Smithsonian.

Dr. Waldo L. Schmitt, curator of marine invertebrates, during the latter part of 1940 served as biologist and leader of the field party organized by the United States Fish and Wildlife Service for the purpose of investigating the biology of the king crab in Alaska. He left Seattle on August 28 and on September 12 established headquarters at Canoe Bay, off the northwest corner of Pavlof Bay, where investigations were carried on successfully for 5 weeks. Later on operations were transferred to Alitak at the western end of Kodiak. Work at a final base on the north side of Shelikof Strait, east of Kukak Bay, from November 15 to 20 ended the investigations for the season, which in addition to observations on the distribution and biology of the king crab yielded an extensive collection of marine animals of interest to the Museum.

Clarence R. Shoemaker, assistant curator of marine invertebrates, in company with T. Kenneth Ellis, undertook a 2-weeks' collecting trip for fresh-water amphipods through Virginia and the Carolinas. The expedition returned with much interesting material to the Museum, the particular object being to extend the study series of certain rare species from this region.

The Smithsonian-Firestone Expedition to Liberia under the leadership of Dr. W. M. Mann, Director of the National Zoological Park,

obtained for the Museum a large amount of zoological and botanical material, including many novelties, from a region of the world hitherto poorly represented in our collections. Although started early in 1940, the expedition did not return until August 7, and is therefore properly referred to here, as the specimens brought back were accessioned during the present year. The story of the expedition has been widely published, and a condensed account with illustrations will be found in the volume Explorations and Field Work of the Smithsonian Institution in 1940, pp. 13–20.

As in past years, Capt. Robert A. Bartlett in his annual expedition to Greenland in the schooner *Morrissey* brought back valuable additions particularly to the invertebrate collections, made with equipment supplied by the Museum.

Dr. Hobart M. Smith, under the Walter Rathbone Bacon scholarship, finished his field work in Mexico in August 1940, bringing back to the Smithsonian Institution splendid collections that in all comprise more than 20,000 specimens of reptiles and amphibians now deposited in the Museum. During July and August, 1940, he was able to study the collection of the late Dr. Alfredo Dugès, which contains many type specimens of Mexican reptiles and amphibians.

Dr. E. A. Chapin, curator of insects, spent 5 weeks on the island of Jamaica during April and May, 1941. Arriving there on April 22, he was met at customs by C. B. Lewis, curator of natural history of the Jamaica Institute, who during the entire period of work assisted in various ways. Special trips arranged by Mr. Lewis included a day on Goat Island, 1 on Portland Ridge, 2 at Cuna Cuna Pass, and a 4-day stay at Cinchona in the Blue Mountains. Except for 8 days spent in and around Savanna-la-Mar, headquarters was maintained near Kingston and short trips were made out from that point. Because of the poor showing made in certain groups in 1937, it was decided to concentrate on the termite and ant faunas. In addition to various rare beetles, at least 13 species of termites, mostly of the type living in hardwood, were found, and at least 3 of them are additions to the Jamaica list. Other results of the work include the establishment of very pleasant relations with the Jamaica Institute and the Government Entomologist's Office.

The United States Antarctic Service expedition returned from a year's stay in the Antarctic with very valuable material consisting of mammals, birds, and a considerable collection of lower cryptogamic plants. The Museum was represented in this work by Herwil M. Bryant. J. E. Perkins and M. J. Lobell were detailed to the expedition by the Fish and Wildlife Service of the Department of the Interior.

Local field work in nearby Maryland and Virginia by various members of the staff has included investigations of Dr. L. P. Schultz

on fresh-water fishes. Botanists of the staff gathered material for a proposed new Flora of the District of Columbia, the object sought being a thorough knowledge of the Washington-Baltimore region.

Geology.—Under a cooperative arrangement with the United States Geological Survey, Dr. W. F. Foshag, curator of mineralogy and petrology, accompanied by Carl Fries, of the Geological Survey staff, made a 3-month survey of the tin resources of Mexico. All the important mining districts of Mexico included within the states of Michoacán, Hidalgo, San Luis Potosí, Queretaro, Aguascalientes, Jalisco, Zacatecas, and Durango were visited and the deposits studied as to their geology, mineralogy, and commercial potentialities. The largest potential deposits are the placer sands derived from granite intrusions in San Luis Potosí. The deposits in the rhyolitic rocks are, in most cases, small and of little importance.

Dr. C. E. Resser, curator of stratigraphic paleontology, spent 3 months in field work, chiefly in the Rocky Mountains, assisted by Charles H. Frey, 3d, of Lancaster, Pa. Dr. Resser left Washington on June 25, making first a brief stop in southwestern Virginia. His next objective was the Cambrian section in the Ozark Mountains, where several days' work enabled him to familiarize himself with these strata. Only indifferent fossils were found, as most of the Cambrian rock does not carry fossils. He continued then to examine Cambrian deposits in Colorado in the Front, Mosquito, and Sawatch Ranges and the Glenwood Springs Canyon. Ten days in the State permitted examination of several sections. Dr. T. S. Lovering, of Ohio State University, who was mapping the region about Gilman, assisted materially in showing the sections there. At the Grand Canyon National Park in Arizona Dr. Resser examined new localities under the guidance of Park Naturalist Edwin McKee during a 3-day trip to Peach Springs and Meriwitica Canyons, 150 miles west of Grand Canyon Village. Some fossils were found and physical measurements made. In the Wasatch Mountains the party checked on the position of certain faunas and on the stratigraphy, which had been questioned. Fine collections were made at critical points. At the Green River Lakes, one of the most beautiful spots in America, Dr. Resser's party found a section 850 to 1,000 feet thick, representing both Middle and Upper Cambrian, carrying a few fossils. Several sections were studied in Montana, notably on Squaw Creek in the Gallatin Range, Newland Creek, Little Birch Creek, and Deep Creek in the Belt Mountains, and several localities near Three Forks, Mont. Particularly fine material was secured at several of these localities. Advantage was taken of the new road constituting the northeastern entrance to the Yellowstone to study the excellent section at Beartooth Butte. Here some good collections were made. On the return

journey a new section across the Big Horn Mountains was seen along Shell Creek, and about a week was spent in the Black Hills. During an earlier trip from May 5 to 15 to southwestern Virginia and eastern Tennessee Dr. Resser examined outcrops of the belt west of Clinch Mountain to ascertain the faunal content of the Maryville formation. Fossils were scarce and very difficult to free from the matrix. A visit to Austinville, Va., furnished some excellent fossils, and observations confirmed earlier interpretation of the stratigraphy. The exact stratigraphic position of a new brachiopod related to *Nisusia*—as yet undescribed—was discovered.

In August 1940 Dr. G. Arthur Cooper, assistant curator of stratigraphic paleontology, joined Mrs. J. H. Renfro and daughter in Fort Worth and with the guidance of these expert collectors collected Pennsylvanian fossils in the region around Jacksboro and Graham in north-central Texas. An abundance of fine material for the biological series was obtained. Following 2 weeks in north-central Texas, Dr. Cooper went to the Glass Mountains in west Texas, where he spent another 2 weeks collecting limestone containing silicified specimens. About a ton of blocks was sent back to Washington, where almost half the material has since been etched with acid, yielding very beautiful rare fossils that preserve the delicate spines, and peculiar features of the interior of the animals concerned in a truly remarkable way. Proceeding to west Tennessee he collected Silurian and Lower Devonian fossils along the Tennessee River in localities that soon will be lost through the impounding of water behind the Gilbertsville, Ky., dam. At places the Silurian in this part of Tennessee teems with fossils of many kinds and fine collections were obtained, including new forms as well as many others not previously present in the collections. From there he went east to Murfreesboro, Tenn., where he joined Dr. Josiah Bridge, of the United States Geological Survey. They spent 10 days in the Central Basin of Tennessee collecting the fossils and studying the rocks of the Stones River (Ordovician) group, as problems of correlation never satisfactorily solved exist in this area.

As the vertebrate paleontological field exploration under Dr. C. L. Gazin, assistant curator of vertebrate paleontology, extended into the present year, but brief mention was made of it in last year's report. The expedition, into central Utah and southwestern Wyoming, was a continuation of previous investigations. In the Upper Cretaceous several additional lizard skeletons were collected; and in the Paleocene a considerable number of fragmentary mammal specimens. Interesting new forms contribute information to the known fauna of the Dragon formation. The bulk of the season was spent in the Bridger formation of the Eocene in southwestern

Wyoming, where 149 lots of fossil specimens were obtained. A skeleton of *Uintatherium* complete enough to articulate for exhibition, probably the most complete skeleton of this animal yet discovered, was the outstanding specimen collected. Partial skeletons of *Palaeosyops* are also of high importance.

Short trips to the Miocene along Chesapeake Bay for cetacean remains were made by Dr. Remington Kellogg and other members of the staff. Many specimens from this unique fauna have been added to the collections.

MISCELLANEOUS

Visitors.—A total of 2,505,871 visitors at the various Museum buildings was recorded during the year, this being virtually the same as for the previous year. The high months this year were August 1940 and April 1941, when 369,942 and 320,594 visitors, respectively, were recorded. The attendance in the four Museum buildings was as follows: Smithsonian Building (main hall closed from July 1 to January 19), 212,464; Arts and Industries Building, 1,302,210; Natural History Building, 803,516; Aircraft Building (closed from March 17 to June 30), 182,112.

Publications and printing.—The sum of $23,000 was available during the fiscal year 1941 for the publication of the annual report, Bulletins, and Proceedings. Twenty-five publications were issued—the annual report, 1 Bulletin, 1 volume of Bulletin 100, 1 separate paper from another volume of Bulletin 100, 1 title page, table of contents, and index of the Contributions from the United States National Herbarium, 19 separate Proceedings papers, and 1 title page, table of contents, and index of a Proceedings volume. Particularly outstanding were the following: "Life Histories of North American Cuckoos, Goatsuckers, Hummingbirds, and Their Allies," by Arthur Cleveland Bent (Bulletin 176); "The Fishes of the Groups Elasmobranchii, Holocephali, Isospondyli, and Ostariophysi Obtained by the United States Bureau of Fisheries Steamer *Albatross* in 1907 to 1910, Chiefly in the Philippine Islands and Adjacent Seas," by Henry W. Fowler (Bulletin 100, volume 13); "Further Studies on the Opalinid Ciliate Infusorians and Their Hosts," by Maynard M. Metcalf; "The Cuban Operculate Land Mollusks of the Family Annulariidae, Exclusive of the Subfamily Chondropominae," by Carlos de la Torre and Paul Bartsch; "A Supposed Jellyfish from the Pre-Cambrian of the Grand Canyon," by R. S. Bassler; "Notes on Birds of the Guatemalan Highlands," by Alexander Wetmore; and "The Chicora (Butler County, Pa.) Meteorite," by F. W. Preston, E. P. Henderson, and James R. Randolph.

Volumes and separates distributed during the year to libraries, institutions, and individuals throughout the world aggregated 52,170 copies.

Special exhibits.—Fourteen special exhibits were held during the year under the auspices of various educational, scientific, recreational, and governmental groups. In addition the department of engineering and industries arranged 17 special displays—8 in graphic arts and 9 in photography.

CHANGES IN ORGANIZATION AND STAFF

In the department of anthropology, Dr. Joseph E. Weckler, Jr., was appointed assistant curator, division of ethnology, on March 1, 1941.

In the department of biology, on the retirement of Gerrit S. Miller, Jr., curator of the division of mammals, the duties of this office were, on January 1, 1941, assumed by Dr. Remington Kellogg, advanced from the position of assistant curator. To the division of insects Dr. Richard E. Blackwelder was appointed as assistant curator on October 1, 1940; to the section of taxidermy Edgar G. Laybourne was appointed senior scientific aid on March 20, 1941, and to the division of birds, John S. Webb was appointed scientific aid on August 1, 1940.

In the department of engineering and industries, to the division of graphic arts Irwin Lefcourt was appointed scientific aid, on September 3, 1940.

Other changes in appointment on the staff were as follows: Elisabeth P. Hobbs to assistant librarian, on March 16, 1941; Ralph A. Silbaugh, foreman of laborers, on January 16, 1941; David L. Hubbs to acting foreman of laborers, on September 1, 1940; Ernest Desantis to lieutenant of guard, on July 1, 1940; and two principal guards (sergeants), James C. Clarke, on July 1, 1940, and Bascom F. Gordon, on March 16, 1941.

Honorary appointments in connection with the National Museum collections were made by the Smithsonian Institution as follows: On July 1, 1940, Walter W. Taylor, Jr., as collaborator in the department of anthropology; on January 1, 1941, Gerrit S. Miller, Jr., as associate in the department of biology.

The scientific staff lost the services of Miss Margaret W. Moodey, by resignation, on May 31, 1941.

Five employees were furloughed indefinitely for military service, namely: Robert E. Kirk, on October 4, 1940; John J. Queeney, on August 15, 1940; Charles E. Stousland, on November 27, 1940; Charles A. Bono, on May 21, 1941, and George V. Worthington, on August 21, 1940.

During the year 13 persons were retired, as follows: Through age: Gerrit S. Miller, Jr., curator, division of mammals, on December 31, 1940, with 40 years 10 months of service; Gertrude L. Woodin, assistant librarian, on January 31, 1941, with 34 years 11 months of service; Joseph T. Saylor, foreman of laborers, on December 31, 1940, with 30 years 8 months service; David H. Zirkle, guard, on June 30, 1941, wtih 15 years of service; Hattie L. Henson, charwoman, on March 31, 1941, with 19 years 6 months of service; and Emma D. Whitley, charwoman, on March 31, 1941, with 15 years of service.

Through optional retirement: Anne J. B. DePue, telephone operator, on November 30, 1940, with 40 years 5 months of service; and Donald MacDonald, guard, on September 30, 1940, with 33 years 9 months of service.

Through disability retirement: Trezzvant Anderson, guard, on March 31, 1941; Eugene Smith, guard, on June 18, 1941; Anna M. Bowie, laborer, on March 14, 1941; Charles Davis, laborer, on June 30, 1941, and Lish Myers, laborer, on April 30, 1941.

Through death, the Museum lost during the year two employees from its active roll, Clayton R. Denmark, engineer, on December 22, 1940, and William G. Shields, guard, on May 31, 1941. From its list of honorary workers, the Museum lost by death, on January 12, 1941, Charles W. Stiles, associate in zoology, division of marine invertebrates, since April 17, 1894, and on June 4, 1941, David I. Bushnell, Jr., who served temporarily from May to June 1913 as archeologist and from July 27, 1932, to his death as collaborator in anthropology.

Respectfully submitted.

ALEXANDER WETMORE, *Assistant Secretary.*

DR. C. G. ABBOT,
Secretary, Smithsonian Institution.

APPENDIX 2

REPORT ON THE NATIONAL GALLERY OF ART

SIR: I have the honor to submit, on behalf of the Board of Trustees of the National Gallery of Art, the fourth annual report of the Board covering its operations for the fiscal year ended June 30, 1941.

Such report is being made pursuant to the provisions of the act of March 24, 1937 (50 Stat. 51), as amended by the public resolution of April 13, 1939 (Pub. Res. No. 9, 76th Cong.). Under this act Congress created, in the Smithsonian Institution, a bureau to be directed by a board to be known as the "Trustees of the National Gallery of Art," charged with the maintenance and administration of the National Gallery of Art, appropriated to the Smithsonian Institution the area bounded by Seventh Street, Constitution Avenue, Fourth Street, and North Mall Drive (now Madison Drive) Northwest, in the District of Columbia, as a site for a National Gallery of Art, and authorized the Smithsonian Institution to permit The A. W. Mellon Educational and Charitable Trust, a public charitable trust established by the late Hon. Andrew W. Mellon, of Pittsburgh, Pa., to construct thereon a building to be designated the "National Gallery of Art." Further, the act authorizes the Board to accept, for the Smithsonian Institution, and to hold and administer gifts, bequests, and devises of money, securities, or other property for the benefit of the National Gallery of Art; also, under the creating act, the United States is pledged to provide such funds as may be necessary for the upkeep of the National Gallery of Art and the administrative expenses and costs of operation thereof, including the protection and care of the works of art so that the Gallery shall at all times be properly maintained and the works of art exhibited regularly to the general public, free of charge.

COMPLETION AND OCCUPATION OF THE GALLERY BUILDING

Formal notice of the completion of the National Gallery of Art project, calling for the construction of the Gallery building and the landscaping of the area appropriated for the site of the National Gallery of Art, in accordance with plans and specifications approved by the Commission of Fine Arts, was given by the Trustees of The A. W. Mellon Educational and Charitable Trust under date of November 30, 1940, to the Trustees of the National Gallery of Art and the Smithsonian Institution, and as provided in the trust indenture

dated June 24, 1937, the legal title to the building was deemed forthwith to be vested in the Smithsonian Institution, of which the National Gallery of Art is a bureau, and the maintenance and administration of the building and site became the exclusive and sole obligation of the Trustees of the National Gallery of Art. A copy of the notice of completion is attached to this report, as exhibit A (not printed).

The Gallery building was turned over to the Trustees of the Gallery on December 1, 1940, and following inspection and upon certification by Eggers and Higgins, successors of John Russell Pope, architect for the Gallery, as to the final completion of the project, the Trustees of the Gallery, at a meeting held December 10, 1940, formally accepted the Gallery project. Copy of the architect's certificate is attached to this report, as exhibit B (not printed). At this meeting the members of the Board expressed great satisfaction with the construction of the Gallery building, as finally completed, and their appreciation of the efforts of the Trustees of The A. W. Mellon Educational and Charitable Trust, the surviving Trustees being Paul Mellon, Donald D. Shepard, and David K. E. Bruce, in the erection of a Gallery building of such monumental character and such outstanding architectural merit.

The Trustees have been apprised that the total cost of the Gallery, including approaches and the landscaping of the site, amounted to $15,035,597.50.

The small nucleus of the Gallery staff, which was housed in offices furnished by The A. W. Mellon Educational and Charitable Trust, moved into the building on November 27, 1940, and proceeded with the work of installation of furnishings and equipment. By December 1, 1940, the nuclear staff, consisting of curatorial and clerical employees, mechanical, guard, and cleaning force, had been organized sufficiently to take over the administration and maintenance of the Gallery building by the Trustees.

During the first days of January 1941, the works of art in the Mellon Collection were moved into the building, and during January, February, and March the works of art in the Kress Collection were received from New York.

Installation of the works of art in the two collections in the galleries prepared for them was undertaken immediately upon their receipt in the new building, and was completed the first week of March.

DEDICATION CEREMONIES AND OPENING OF THE GALLERY TO THE PUBLIC

On the evening of March 17, 1941, 8,822 invited guests attended the opening ceremonies. Included among the invited guests were the members of the Cabinet, Senate, and House of Representatives,

Government officials, the diplomatic corps, artists, art critics, heads of educational institutions, persons generally interested in art, and other distinguished guests.

The ceremonies, a half-hour program, with Chief Justice Charles Evans Hughes as the presiding officer, began at 10 o'clock, with an invocation by the Reverend ZeBarney Thorne Phillips, Chaplain of the Senate. Following a brief talk by the Chief Justice on the object and purposes of the Gallery project, Paul Mellon, son of the late Andrew W. Mellon, the donor of the Gallery, on behalf of his father and the Trustees of the Mellon Trust, presented the Gallery and the Mellon Collection to the Nation. Samuel H. Kress then presented the Kress Collection of Italian paintings to the Gallery. The President of the United States accepted the Gallery and the Mellon and Kress Collections on behalf of the people of the United States. A copy of the President's address, and that of Chief Justice Hughes, are attached to this report, as exhibit C (not printed). The ceremonies closed with the National Anthem, led by the United States Marine Band. During the early part of the evening, there was a preview of the Gallery collections. Orchestras played in the garden courts, decorated with the famous Widener collection of acacias, which had been given to the Nation for the joint use of the Gallery and the United States Botanic Garden, and tropical plants.

On the following day, March 18, 1941, the Gallery was opened to the public and was viewed by large crowds. In accordance with the decision of the Board of Trustees, the Gallery building is open every day in the year, except Christmas and New Year's day. The hours are 10 a. m. to 5 p. m. on week days and 2 p. m. to 5 p. m. on Sundays.

ORGANIZATION AND STAFF

The statutory members of the Board are the Chief Justice of the United States, the Secretary of State, the Secretary of the Treasury, and the Secretary of the Smithsonian Institution, ex officio, and five general trustees. The general trustees, serving during the fiscal year ended June 30, 1941, were David K. E. Bruce, Duncan Phillips, Ferdinand Lammot Belin, Joseph E. Widener, and Samuel H. Kress. In May 1941 the general trustees elected Ferdinand Lammot Belin, whose term of office would expire on July 1, 1941, to succeed himself as a general trustee, to serve as such until July 1, 1951. At the meeting of the Board held on June 20, 1941, the resignation of Chief Justice Charles Evans Hughes was accepted by the Trustees with great regret, to take effect July 1, 1941, and in doing so the Board adopted the following resolutions:

Whereas the Honorable Charles Evans Hughes has resigned as Chief Justice of the United States and has consequently tendered his resignation as Chairman of the Board of Trustees of the National Gallery of Art, effective July 1, 1941;

And whereas the Board of Trustees has learned of his resignation with profound regret;

Therefore, be it resolved, That the members of the Board of Trustees record their sense of the loss which the Gallery has sustained in being deprived of the services of Chief Justice Hughes;

And be it also resolved, That the Board hereby expresses its grateful appreciation for the devotion with which he has carried out his duties as Chairman, and for the wisdom and unfailing courtesy with which he has guided the affairs of the National Gallery during the critical years of its formative period;

And be it further resolved, That the Board wishes to express to him its high regard and best wishes that he may enjoy many years of health and happiness after his long career of distinguished public service to his country.

Pursuant to the provision of the act of March 24, 1937, the newly appointed Chief Justice of the United States, the Honorable Harlan F. Stone, who succeeds Chief Justice Hughes, will serve as an ex officio trustee of the Gallery.

The Board at its annual meeting held February 10, 1941, reelected David K. E. Bruce, President, and Ferdinand Lammot Belin was reelected Vice President of the Board to serve for the ensuing year. The executive officers who continued in office were Donald D. Shepard, Secretary-Treasurer and General Counsel; David E. Finley, Director; Harry A. McBride, Administrator; John Walker, Chief Curator; and Macgill James, Assistant Director. Other officers of the Gallery continuing in office were Charles Seymour, Jr., curator of sculpture; George T. Heckert, assistant to the administrator; and Sterling P. Eagleton, chief engineer and building superintendent. During the year Charles Zinsner was appointed assistant treasurer and the following honorary officers were appointed by the Board: Alexander R. Reed, building consultant; Alfred Geiffert, Jr., consultant landscape architect; and William A. Frederick, consultant horticulturist.

The three standing committees of the Board, provided for in the bylaws, as constituted at the annual meeting of the Board, held February 10, 1941, were:

EXECUTIVE COMMITTEE

Chief Justice of the United States, Charles Evans Hughes.
The Secretary of the Smithsonian Institution, Dr. C. G. Abbot.
David K. E. Bruce.
Ferdinand Lammot Belin.
Duncan Phillips.

FINANCE COMMITTEE

The Secretary of the Treasury, Henry Morgenthau, Jr.
The Secretary of State, Cordell Hull.
David K. E. Bruce.
Ferdinand Lammot Belin.
Samuel H. Kress.

ACQUISITIONS COMMITTEE

David K. E. Bruce.
Duncan Phillips.
Joseph E. Widener.
Ferdinand Lammot Belin.
David E. Finley.

Other standing committees appointed by the Board during the year: A committee to make recommendations as to the acceptance or rejection of gifts of property other than works of art, monies, and securities; a committee on public relations; and a committee on the building.

During the first half of the year all of the civil service positions for the Gallery staff had been classified and by March 1, 1941, practically all of the initial staff of the Gallery, including the curatorial, clerical, custodial, and maintenance personnel had been employed. On June 30, 1941, 229 civil service employees were on the Gallery staff. Among such employees were the chief docent, the librarian, and the registrar.

The cataloging of the works of art was completed so that it was possible to issue the first catalog of the National Gallery by March 17, 1941, the date of the opening.

The guard force was organized to assure not only efficiency in the protection of the works of art and of the building and grounds, but also to assure a high quality of service to the public.

APPROPRIATIONS

For salaries and expenses, for the upkeep and operation of the National Gallery of Art, the protection and care of the works of art therein, and all administrative expenses incident thereto, as authorized by the act of March 24, 1937 (50 Stat. 51), as amended by the public resolution of April 13, 1939 (Pub. Res. No. 9, 76th Cong.), there was appropriated for the fiscal year ending June 30, 1942, the sum of $533,300. Of the $300,000 appropriated by Congress for the period July 1, 1940, to June 30, 1941 (54 Stat. 137), $298,543.14 was expended or encumbered, in the following detailed amounts, for personal services, printing and binding, and supplies and equipment, leaving an unencumbered appropriation of $1,456.86. This appropriation was based, of course, upon part-year operation and expenditures were made therefrom as follows:

EXPENDITURES AND ENCUMBRANCES

Personal services	171,786.18
Printing and binding	7,352.51
Supplies and equipment	119,404.45
Total	$298,543.14

ATTENDANCE

The total attendance from March 17 to June 30, the end of the fiscal year, was 798,156, an average of 7,529 persons per day. The greatest number of visitors in any one day was 24,745 on March 23, 1941.

A booklet of general information on the Gallery, containing a check list of paintings and sculpture and floor plans, supplied from Government funds, has been found of great assistance to the visitors to the Gallery. There is no charge for this booklet and a copy is given to visitors who request one.

PUBLICATIONS FUND

Through the Publications Fund it was possible to have ready for the opening of the Gallery, not only a catalog, but also a complete Book of Illustrations of all the works of art in the collections of the National Gallery; color reproductions; and postcards, both in color and in black and white. These publications are on sale at moderate cost in the Information Rooms.

ACQUISITIONS

GIFTS OF PRINTS

On March 13, 1941, the Board of Trustees accepted from Miss Ellen T. Bullard and three anonymous donors a number of important prints; and again on June 20, 1941, the Board accepted a number of additional important prints from one of the anonymous donors who had previously made a gift of prints to the Gallery, all of which are listed in exhibit D (not printed). Also on June 20, 1941, the Board accepted as a gift from Lessing Rosenwald of Jenkintown, Pa., a collection of important engravings, etchings, and woodcuts, which are listed in exhibit D (not printed).

GIFTS OF PAINTINGS

On February 10, 1941, the Board of Trustees accepted from Mrs. Felix M. Warburg the gift of two valuable paintings:

Triptych attributed to the School of Pietro Lorenzetti
"The Preaching of Savonarola," by Domenico Morone

as a memorial to her husband, the late Felix M. Warburg. The paintings have been received and will be exhibited with the Permanent Collection.

On June 20, 1941, the Board of Trustees accepted from Duncan Phillips, a trustee of the Gallery, the gift of an important painting

by Honoré Daumier, entitled "Advice to a Young Artist," for exhibition with the Permanent Collection. Also on June 20, 1941, the Board accepted from Mrs. David K. E. Bruce the gift of a portrait of her father, the late Andrew W. Mellon, by Oswald Birley, which has been hung over the mantel in the Founder's Room.

During the year other offers of gifts of works of art were received but were not accepted because, in the opinion of the Board, they were not considered to be desirable acquisitions for the Permanent Collection as contemplated by section 5 of the act of March 24, 1937 (50 Stat. 51).

OTHER GIFTS

During the year there were also gifts to the Gallery of furnishings, equipment, materials and supplies, ornamental trees and plants, books and publications, from the Trustees of The A. W. Mellon Educational and Charitable Trust and others.

SALE OR EXCHANGE OF WORKS OF ART

During the year no works of art belonging to the Gallery were sold or exchanged.

LOANS OF WORKS OF ART TO THE GALLERY

During the year the following works of art were received on loan:

An anonymous loan:

20 Rembrandt prints—listed on the attached exhibit D (not printed).

From Dr. Horace Binney, of Milton, Mass.:

A portrait of his ancestor, the Honorable Horace Binney, by Gilbert Stuart.

From Chester Dale, of New York, the following paintings of the American School:

Artist	*Subject*
John Smibert	Portrait of Oxenbridge Thacher of Milton.
Thomas Sully	The Sicard David Children—Julia, Ferdinand, and Stephen.
Jeremiah Theus	Portrait of a Woman in Red Dress.
John Neagle	Portrait of John Rush.
Thomas Sully	Portrait of Mrs. William Griffin.
S. F. B. Morse	Portrait of Mrs. Henry John Auchmuty.
Do	Portrait of a Lady.

From Samuel H. Kress and the Samuel H. Kress Foundation:

43 paintings and 22 pieces of sculpture, listed in exhibit D (not printed).

From The A. W. Mellon Educational and Charitable Trust:

187 paintings, many of which were formerly in the Clarke Collection, for an indefinite period to be held for study, exhibition, or use as may be provided by

the acquisitions committee. (See exhibit D, not printed.) The following paintings from the collection have been placed on exhibition as loans:

Artist	*Subject*
Robert Feke	Williamina Moore.
Gilbert Stuart	Richard Yates.
Do	George Washington
Do	George Pollock.
Do	Joseph Anthony.
John Wollaston	Mary Walton Morris.

From Duncan Phillips, a trustee of the Gallery:

Artist	*Subject*
Corot	The Dairy Farm.
Courbet	The Rocks at Ornans.

From John Cooper Wiley:

Russian icon of the thirteenth century, for study and exhibition in the collection if considered desirable.

LOAN OF WORKS OF ART BY THE GALLERY

During the year no works of art belonging to the Gallery were placed on loan.

RESTORATION AND REPAIRS TO WORKS OF ART

During the year, as authorized by the Board and with the approval of the Director and the Chief Curator, Stephen Pichetto, consultant restorer to the Gallery, has undertaken such work of restoration and repair of paintings and sculpture in the collection as has been found to be necessary.

Prior to the opening of the Gallery to the public, the work was done at Mr. Pichetto's studio in New York, and all works of art have been returned in excellent condition. Since March 17, 1941, such work has been carried on in the restorer's rooms at the Gallery.

CURATORIAL DEPARTMENT

The curatorial work during the first part of the year consisted in installing the National Gallery collections and completing the work on the catalog. The catalog was issued at the opening of the Gallery, and contains brief biographies of all the artists, descriptions of the works of art, and notes indicating the date or approximate date of the paintings and sculpture with such factual information as may be of interest to the student. A book of illustrations of the paintings and sculpture in the National Gallery was also issued under the supervision of the curatorial staff.

During the year 619 works of art were submitted to the acquisitions committee with recommendations as to the acceptability for

the collection of the National Gallery; 16 visits were made to private collections by various members of the staff in connection with offers of gift or loan; expert opinion on 61 works of art was given verbally to various members of the public; and 101 letters were written to persons asking for historical data or other information regarding works of art in their possession.

The curatorial staff also supervised the arrangement of temporary exhibitions held by the Gallery and assisted in the work of the Educational Department.

EDUCATIONAL PROGRAM

The docent staff has been organized so that there are at least two public gallery tours every day and two auditorium lectures every week. This program of instruction for the public has been found to meet a definite need. During the period from March 18 to June 30, 1941, 11,324 persons came to the Gallery as members of special groups or organizations desiring special guidance by members of the docent staff. Many of these were school and college groups, including both instructors and students, from practically every State in the Union.

Two thousand eight hundred and eighty-two individuals have been conducted through the Gallery by members of the docent staff in special gallery tours, available to the general public. Two thousand four hundred and eighty individuals have attended auditorium lectures on the collection presented twice a week by members of the docent staff, beginning April 8, 1941.

In addition, members of the docent staff have conducted private and group conferences for 288 teachers and other individuals interested in and learning about the Gallery and the collection.

LIBRARY

Books and catalogs to the number of 162 were presented to the Gallery; 196 publications were acquired through exchange; and 51 books were purchased.

PHOTOGRAPHIC DEPARTMENT

Since February 16, 1941, 6,356 prints have been made by the photographic laboratory. Many were used in connection with the opening of the Gallery on March 17, 1941. Others are on file in the library, where they are for sale and for the use of the Gallery staff. Lantern slides made for use in connection with free public lectures in the Gallery numbered 341.

EXHIBITIONS

From May 15 to June 5, 1941, an exhibition was held in the central gallery on the ground floor, of 200 American water colors selected by John Marin, Charles Burchfield, Buk Ulreich, and Eliot O'Hara from a National Competition for the Carville, La., Marine Hospital, held by the Section of Fine Arts, Federal Works Agency, Public Buildings Administration. This was the first loan exhibition held at the Gallery and proved a popular one both with the public and with the critics.

MEMORIAL TABLET

At the annual meeting of the Board, on February 10, 1941, the Board authorized the erection of a memorial tablet to the late Andrew W. Mellon, with an inscription in the wording appearing immediately below, under a bas-relief portrait of Mr. Mellon to be done in marble:

ANDREW WILLIAM MELLON

1855–1937

He gave the Building, with his Collection, for the founding of this National Gallery of Art.

For the whole earth is the sepulchre of famous men; and their story is not graven only on stone over their native earth, but lives on far away, without visible symbol, woven into the stuff of other men's lives.

This tablet was installed, prior to the opening of the Gallery, between the then two free standing pillars in the lobby, facing the Constitution Avenue entrance of the Gallery. The bas-relief portrait was executed by Jo Davidson. The cost of the work was contributed by The A. W. Mellon Educational and Charitable Trust.

COMMEMORATIVE TABLET ON THE ERECTION OF THE BUILDING

Also prior to the opening of the Gallery, the Board authorized, and there was installed in the building, a bronze tablet recording the history of the erection of the building, with the names of the donor and others who rendered valuable aid toward the completion of the Gallery project.

MEMORIAL PANELS TO BENEFACTORS OF THE NATIONAL GALLERY OF ART

At the annual meeting of the Board, held February 10, 1941, the Board set aside the four marble panels on the east and west walls

of the Constitution Avenue entrance lobby for the names of important donors to the Gallery, and arranged for the carving at the top of one of the panels the words, "Principal Benefactors of the National Gallery of Art," and beneath, the names "Andrew William Mellon" and "Samuel Henry Kress." The Board further authorized having such names carved in future as may be authorized by it. The carving authorized by the Board was completed before the opening of the Gallery.

AUDIT OF PRIVATE FUNDS OF THE GALLERY

An audit has been made of the private funds of the National Gallery of Art for the year ended June 30, 1941, by Price, Waterhouse & Co., a nationally known firm of public accountants, and the certificate of that company on its examination of the accounting records maintained for such funds has been submitted to the Gallery. The financial statement referred to above is attached to this report, as exhibit E (not printed).

Respectfully submitted.

F. L. BELIN, *Vice President.*

Dr. C. G. ABBOT,
Secretary, Smithsonian Institution.

APPENDIX 3

REPORT ON THE NATIONAL COLLECTION OF FINE ARTS

SIR: I have the honor to submit the following report on the activities of the National Collection of Fine Arts for the fiscal year ended June 30, 1941:

Two bequests were received, namely, $5,000 from the Cornelia Livingston Pell Estate of New York, and $10,000 from the Julia D. Strong Estate of Washington, D. C.

Several proffered gifts of etchings, miniatures, and paintings have been deposited here to be passed upon by the Smithsonian Art Commission in December 1941.

Eight special exhibitions were held in the foyer involving the installation of over 900 specimens. Eight special Graphic Arts exhibits were shown in the lobby because of alterations in the Smithsonian Building.

Three paintings were restored for the Comptroller of the Currency, Treasury Department: "Portrait of Charles G. Dawes," by Zorn, "Portrait of Henry W. Cannon," by T. W. Wood, and "Portrait of John Jay Knox," by Eastman Johnson.

Illustrated lectures were delivered by Mr. Tolman, the Acting Director, before the American Association of University Women on January 30, 1941, and before a group of young Italian art lovers at the Ambassador Hotel on February 19, 1941.

APPROPRIATIONS

For the administration of the National Collection of Fine Arts by the Smithsonian Institution, including compensation of necessary employees, purchase of books of reference and periodicals, traveling expenses, uniforms for guards, and necessary incidental expenses, $41,715 was appropriated, of which $32,006.84 was expended for the care and maintenance of the Freer Gallery of Art, a unit of the National Collection of Fine Arts, and $1,585 for the salary for 11 months of one clerk in the Smithsonian Institution. The balance of $8,123.16 was spent for the care and upkeep of the National Collection of Fine Arts, nearly all of this sum being required for the payment of salaries, traveling expenses, books, periodicals, and necessary disbursements for the care of the collection.

THE SMITHSONIAN ART COMMISSION

The twentieth annual meeting of the Smithsonian Art Commission was held on December 3, 1940. The members met at 10:30 in the Natural History Building, where, as the advisory committee on the acceptance of works of art which had been submitted during the year, they accepted the following:

"Sunny Slopes," by Gardner Symons (1863–1930). Gift of Mrs. Louis Betts, formerly Mrs. Gardner Symons.

"Portrait of George Fuller (1822–1884)," and "Self Portrait," by William Baxter Closson (1848–1926). Gift of Mrs. William Baxter Closson.

"Portrait of Dr. William H. Holmes (1846–1933)," by Nicholas R. Brewer (1857–). Gift of Mrs. Nicholas Webster, daughter of DeLancey Gill.

After a visit to the National Gallery of Art building, then almost completed, the members assembled in the regents' room in the Smithsonian Building for the further proceedings, the meeting being called to order by the Chairman, Mr. Borie, at 12:30.

The members present were: Charles L. Borie, Jr., chairman; Frank Jewett Mather, Jr., vice chairman; Dr. Charles G. Abbot (ex officio), secretary; and Louis Ayres, Gifford Beal, Gilmore D. Clarke, David E. Finley, James E. Fraser, Frederick P. Keppel, John E. Lodge, Paul Manship, Edward W. Redfield, and Mahonri M. Young. Ruel P. Tolman, curator of the division of graphic arts in the United States National Museum and acting director of the National Collection of Fine Arts, was also present.

The following resolutions on the death of Mr. McClellan were submitted and adopted:

Whereas, the Smithsonian Art Commission has learned of the death on November 30, 1940, of Col. George B. McClellan, a member of this Commission since 1931; therefore be it

Resolved, That the Commission desires to record its sincere sorrow at the loss of Mr. McClellan, who as a man and a collector had the respect of the entire Commission. His advice and suggestions were always timely and valuable, and as a friend he will be deeply missed.

Resolved, That these resolutions be spread upon the records of the Commission, and that the Secretary of the Commission be requested to convey this action to the family of Mr. McClellan with an expression of our deepest sympathy in their bereavement.

A set of rules for the National Portrait Gallery, prepared by Mr. McClellan, chairman of the executive committee, was submitted. Professor Mather offered an amendment to rule 3 which was accepted. By motion, the Commission adopted the entire set of rules as amended, subject to any later modifications that may be made. They read:

SUGGESTED RULES FOR THE ADMISSION OF PORTRAITS TO THE NATIONAL PORTRAIT GALLERY PREDICATED ON THOSE OF THE BRITISH NATIONAL PORTRAIT GALLERY

1. Admission of a portrait to the Gallery shall be based primarily on the celebrity of its subject rather than on its artistic merit. Such celebrity shall have been acquired from the subject's contribution to the history or development of the United States regardless of his or her opinions, words, or deeds.

2. No portrait of any living person shall be admitted to the Gallery unless such portrait is that of one of a group of persons at least a majority of whom are dead.

3. No portrait of any person dead less than 20 years shall be admitted to the Gallery except by unanimous vote by individual ballot of those present at a meeting of the Commission.

4. No gift or bequest shall be accepted or portrait purchased except by a three-fourths vote of the members present at the meeting of the Commission.

The Commission recommended to the Board of Regents the reelection of John E. Lodge, David E. Finley, Edward W. Redfield, and Paul Manship.

The following officers were reelected for the ensuing year: Charles L. Borie, Jr., chairman; Frank Jewett Mather, Jr., vice chairman, and Dr. Charles G. Abbot, secretary.

The following were elected members of the executive committee for the ensuing year: Herbert Adams, Gilmore D. Clarke, John E. Lodge. Charles L. Borie, Jr., as chairman of the Commission, and Dr. Charles G. Abbot, as secretary of the Commission, are ex-officio members of the executive committee.

The chairman stated that as the competition for the plans for the Smithsonian Gallery of Art had come to an end and no funds had been obtained for further work on the project, there was nothing to report.

Mr. Clarke and the Secretary also addressed the Commission in regard to the activities connected with the recent competition for the plans for the Gallery, but no action was taken, although the members expressed the feeling that the Commission was ready to take active steps whenever funds were available to advance the project.

THE CATHERINE WALDEN MYER FUND

Three miniatures were acquired from the fund established through the bequest of the late Catherine Walden Myer, as follows:

22. "Portrait of a Young Man," by Moses B. Russell; from Miss Alice G. Rogers, Old Lyme, Conn.

23. "Le Chevalier Ed. van Cockelberghe de Dulzele of Belgium," by an unknown artist; from Samuel M. Crockett, Lynn, Mass.

24. "Antoinette Bates," by Thomas Sully; from Mrs. Eva Wilson Chadbourne, Washington, D. C.

LOANS ACCEPTED

Two oil paintings, "My Mother" and "The Dawn," by E. Hodgson Smart, were lent by the artist.

Three pastels, "The Cliffs Aflame," "Portrait (Patsy)," and "Sunshine and Pine Needles," and seven oil paintings, "Looking Far Out," "The Woodland Way," "The Butterfly Dance," "Joyous Childhood," "The Red Barn," "Peonies," and "Springtime," by William Baxter Closson, were lent by the artist's widow.

LOANS TO OTHER MUSEUMS AND ORGANIZATIONS

The following five paintings were lent to the Carnegie Institute, Pittsburgh, Pa., for a Survey of American Painting from October 24 through December 15, 1940: "Sunset, Navarro Ridge, California Coast," by Ralph A. Blakelock; "Cliffs of the Upper Colorado River, Wyoming Territory," by Thomas Moran; "Moonlight," by Albert P. Ryder; "Fired On," by Frederic Remington, and "Visit of Nicodemus to Christ," by John La Farge. (Returned January 7, 1941.)

Two paintings, "The Cup of Death," by Elihu Vedder, and "Christ Before Pilate," by Walter Beck, were lent to the Howard University Gallery of Art, Washington, D. C., to be included in an exhibition of Christian Art in connection with the twenty-fourth annual convocation of the School of Religion from November 12 to December 23, 1940. (Returned January 9, 1941.)

One painting, "Sheepyard—Moonlight," by Horatio Walker, was lent to The Art Gallery of Toronto, Canada, for an exhibition of two Canadian painters, Horatio Walker and Tom Thomson. The painting was also shown in the National Gallery of Canada at Ottawa and the Art Association at Montreal. (Returned April 28, 1941.)

WITHDRAWALS BY OWNERS

Two portraits in pastel, by James Sharples (c.1751–1811), of Gen. James Miles Hughes (1756–1802), original member of the Society of the Cincinnati, and Mrs. James Miles Hughes, his wife, were withdrawn by the owner, Mme. Florian Vurpillot, on November 5, 1940.

Marble bust of Samuel Gompers (1850–1924), by Moses W. Dykaar (1884–1933), was withdrawn by the owner, The American Federation of Labor, to be exhibited at the Department of Labor, on November 15, 1940.

An oil painting, "My Mother," by E. Hodgson Smart, was withdrawn by the owner, Mr. Smart, on November 30, 1940.

A pastel, "Sunshine and Pine Needles," by William Baxter Closson (1848–1926), was withdrawn by the owner, Mrs. William Baxter

Closson, and presented to Mr. and Mrs. H. D. Drake, Washington, D. C., on May 5, 1941.

An oil painting, "The Butterfly Dance," by William Baxter Closson (1848–1926), was withdrawn by the owner, Mrs. William Baxter Closson, and presented to Miss Elizabeth Peet, Washington, D. C., on May 5, 1941.

LOANS RETURNED

An oil painting, "Portrait of Mary Hopkinson (wife of Dr. John Morgan)," by Benjamin West, lent to the Masterpieces of Art Exhibition at the New York World's Fair, 1940, was returned September 17, 1940.

A bronze statue of Lincoln, by Augustus Saint Gaudens, lent with the consent of the owners, the estate of Mrs. John Hay, to the New York World's Fair for exhibition in the Illinois Building, was returned November 14, 1940.

THE NATIONAL COLLECTION OF FINE ARTS REFERENCE LIBRARY

A total of 180 publications, including 146 acquired by purchase and 5 by transfer, were accessioned during the year.

THE HENRY WARD RANGER FUND

The following two paintings, purchased by the council of the National Academy of Design from the fund provided by the Henry Ward Ranger bequest, were recalled for action on the part of the Smithsonian Art Commission, in accordance with the provision in the Ranger bequest. The Smithsonian Art Commission decided not to accept the paintings and they were returned to become the absolute property of the museums to which they were originally assigned.

"The Offering," by Charles W. Hawthorne, N. A. (1872–1930), assigned to the Cleveland Museum of Art, Cleveland, Ohio, June 12, 1931.

"Gleam on Hilltops," by Gardner Symons, N. A. (1863–1930), assigned to the Montclair Art Association, Montclair, N. J., June 2, 1922.

SPECIAL EXHIBITIONS

The following exhibitions were held:

October 8 to 25, 1940.—Special exhibition of 48 pastels, drawings, and lithographs by Lily E. Smulders.

November 1 to 24, 1940.—The Sixth Annual Metropolitan State Art Contest, 1940, under the auspices of the Department of Fine Arts of the District of Columbia Federation of Women's Clubs. There were 289 exhibits consisting of paintings, sculpture, and prints by 158 artists.

December 1, 1940, to January 1, 1941.—Special exhibition of the work of William Baxter Closson (1848-1926) consisting of 94 oils,

40 pastels, 21 water colors, 112 wood engravings, intaglio and relief prints by the Closson method with tools and necessary materials, and also medals which had been awarded to him.

January 8 to 29, 1941.—Special exhibition by the National Society of Pastelists. There were 111 pastels by 17 artists.

February 1 to 26, 1941.—Special exhibition of 22 water colors and 21 pastels by Ethel H. Hagen.

May 15 to 19, 1941.—Special exhibition of 42 paintings by Alejandro Pardinas under the patronage of His Excellency the Cuban Ambassador.

June 2 to 15, 1941.—Special exhibition of 39 caricatures by Antonio Sotomayor under the patronage of His Excellency the Bolivian Minister.

June 3 to 30, 1941.—Special memorial exhibition of 17 color prints and 50 black and white prints by Bertha E. Jaques (1863–1941).

PUBLICATIONS

TOLMAN, R. P. Report on the National Collection of Fine Arts for the year ended June 30, 1940. Appendix 3, Report of the Secretary of the Smithsonian Institution for the year ended June 30, 1940, pp. 38–42.

CATALOG of American and European paintings in the Gellatly Collection, 20 pp., 11 pls. 1940.

LODGE, J. E. Report on the Freer Gallery of Art for the year ended June 30, 1940. Appendix 4, Report of the Secretary of the Smithsonian Institution for the year ended June 30, 1940, pp. 43–48.

Respectfully submitted.

R. P. TOLMAN, *Acting Director.*

DR. C. G. ABBOT,
Secretary, Smithsonian Institution.

APPENDIX 4

REPORT ON THE FREER GALLERY OF ART

SIR: I have the honor to submit the twenty-first annual report on the Freer Gallery of Art for the year ended June 30, 1941.

THE COLLECTIONS

Additions to the collections by purchase are as follows:

BRONZE

40.11.
a–b. Chinese, late Shang dynasty, twelfth century B. C. A ceremonial covered vessel of the type *yu*. Outside, fairly even patination in shades of gray green with flecks of cuprite; inside, cuprite, azurite, and malachite with areas of original metal; little incrustation; cast inscription of one character. 0.361 x 0.269 over all.

40.23. Chinese, late Chou dynasty, sixth-third century B. C. A quadruped, its surface almost entirely covered with linear and countersunk naturalistic and decorative designs. Smooth, gray-green patina with scattered incrustations of green and blue. Vent in the belly. 0.115 x 0.182 over all. (Illustrated.)

41.1. Chinese, late Chou dynasty, fourth century B. C., or earlier. From Chang-sha. A mirror, patinated in shades of gray with slight incrustations of malachite and rust on the obverse; five long-necked birds in linear relief against a background of curl and feather design on the reverse. Diameter: 0.164. (Illustrated.)

41.6.
a–b. Chinese, late Chou dynasty, fifth-fourth century B. C. A garment hook. Sheathed with silver, gilded and ornamented with inlaid turquoise and other stones; engraved designs showing the silver on the back; malachite incrustations. Carved wood stand. Length: 0.221.

41.8. Chinese, Shang dynasty, fourteenth–twelfth century B. C. A ceremonial vessel of the type *tui* (or *chiu*). Gray-green patination with scattered spots of green inside and out; malachite and azurite incrustations on the bottom. Cast inscription of two characters. 0.140 x 0.211 over all.

JADE

41.3. Chinese, early Chou dynasty or earlier, twelfth century B. C. A ceremonial blade of mottled gray-green and gray-white nephrite. 0.266 x 0.103 over all.

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JADE AND BRONZE

41.4. Chinese, Shang dynasty, twelfth century B. C. A ceremonial implement: the blade of mottled gray-brown and white nephrite mounted in bronze closely inlaid with turquoise; socket for vertical shafting; scattered malachite incrustations. Length: 0.213.

41.5. Chinese, Shang dynasty, twelfth century B. C. A ceremonial weapon of the type *ko:* the blade of mottled white nephrite, the tang of bronze ornamented with turquoise inlay; malachite incrustations. 0.418 x 0.223 over all.

MANUSCRIPTS

40.16. Arabic (Persia), thirteenth-fourteenth century. A book bound in tooled brown leather (repaired): *Juz' XVII* of the *Qur'ān*. Text in *thulth* script on 144 paper leaves, three lines to a page, with interlinear Persian translation in *naskhī* script. Illuminated pages, chapter headings and marginal ornaments. 0.277 x 0.178 (single leaf). (Illustrated.)

40.19. Arabic (Persia?), fourteenth century. An illuminated frontispiece from an unidentified book. *Naskhī* script in white on a gold ground; floral scrolls in gold on dark blue and light green; gold borders. Paper: 0.393 x 0.290; illumination: 0.276 x 0.214.

PAINTING

40.17. Indian, Mughal-Rājput, seventeenth centry. A woman standing. In color and gold on paper. 0.127 x 0.063.

40.21. Indian, Rājput (Deccan), early seventeenth century. A woman receiving travelers at the door of a house. In opaque color (somewhat worn) on paper. 0.122 x 0.222.

40.12–40.13. Persian, Mongol (Īl-Khān) period, early fourteenth century. Two additional illustrations belonging to our *Shāhnāmah* ms. 30.1, painted in colors, silver (darkened), black and gold on paper.

.12. Siyāwush attended by Rustam receiving the homage of Garsīwaz. 0.095 x 0.115.

.13. Bīzhan in bonds before Afrāsiyāb. 0.092 x 0.115.

40.14–40.15. Persian, Mongol (Īl-Khān) period, early 14th century. Two illustrations from a *Shāhnāmah*, painted in colors, gold and black on paper.

.14. Pirān presents young Khusraw to Afrāsiyāb. 0.044 x 0.083.

.15. Prisoners of war brought before Shāh Kāwūs. 0.055 x 0.121.

40.18. Persian, sixteenth-seventeenth century. A group of dervishes. Line drawing in black, red, and blue inks; lightly tinted. 0.163 x 0.100.

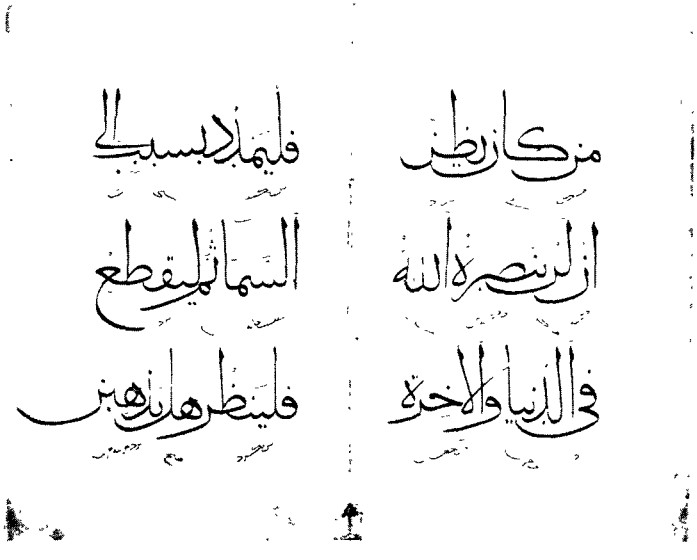
40.20. Persian, Timurid, fifteenth century. An illustration on a leaf from a *Shāhnāmah:* Shāh Kāwūs and Kai Khusraw approach the sacred fire. Painted in colors and gold on paper. 0.095 x 0.160.

PORCELAIN AND POTTERY

41.2. Chinese, K'ang Hsi period, seventeenth-eighteenth century. A porcelain flask, covered with a luminous, pale green glaze. Date mark in blue enamel under the foot. Height, 0.210.



40.22

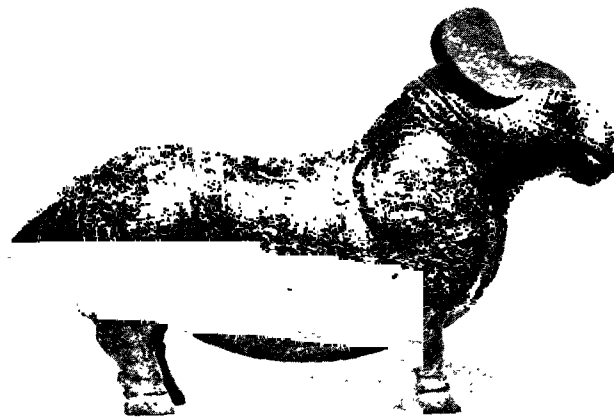


40.16

SOME RECENT ADDITIONS TO THE COLLECTION OF THE FREER GALLERY OF ART.



41.1



40.23

SOME RECENT ADDITIONS TO THE COLLECTION OF THE FREER GALLERY OF ART

41.7. Chinese, Sung dynasty. Incense burner. Soft paste pottery covered with a glossy, celadon blue glaze. 0.095 x 0.110 over all.

40.22. Persian, Kāshān, early fourteenth century. Bowl, of a soft sandy body; the decoration painted in gold luster on a white ground. 0.083 x 0.200. (Illustrated.)

The work of the curatorial staff has been devoted to the study and recording of the new acquisitions listed above, and to other Arabic, Armenian, Chinese, East Indian, Japanese, Persian, and Syrian art objects and manuscripts either already in the collection or submitted for purchase. Other Chinese, Japanese, Arabic, Persian, European, and American objects were sent or brought to the Director by their owners for information as to identity, provenance, quality, date, or inscriptions. In all, 693 objects and 180 photographs of objects were so submitted, and written or oral reports upon them were made to the institutions or private owners requesting this service. Written translations of 24 inscriptions in oriental languages were made upon request, several bibliographies compiled, articles and reviews written, and several Gallery publications revised.

Eighty-four changes were made in exhibition as follows:

Chinese bronze and jade	1
Chinese jade	44
Chinese marble	1
Chinese painting	8
Chinese pottery	30

Repairs, etc., to the collection were as follows:

American painting	1
Chinese panel painting	5
Chinese scroll painting	6
Persian pottery	2
Maps, blueprints mounted	13

ATTENDANCE

The Gallery has been open to the public every day from 9 until 4:30 o'clock, with the exception of Mondays, Christmas Day, and New Year's Day.

The total attendance of visitors coming in at the main entrance was 111,656. One hundred and twenty-eight other visitors on Mondays make the grand total 111,784. The total attendance for week days, exclusive of Mondays, was 79,246; Sundays 32,410. The average week-day attendance was 305; the average Sunday attendance, 623. The highest monthly attendance was, as usual, in April, with 14,280 visitors; the lowest in January, with 5,901.

There were 1,369 visitors to the main office during the year. The purposes of their visits were as follows:

For general information	186
To see objects in storage	370
Far Eastern paintings	50
Near Eastern paintings and manuscripts	19
East Indian paintings and manuscripts	3
American paintings	60
Whistler prints	7
American pottery	5
Oriental pottery, jade, bronzes, and sculpture	133
Syrian, Arabic, and Egyptian glass	11
Byzantine objects	4
Washington Manuscripts	78
To read in the library	172
To make tracings and sketches from library books	6
To see the building and installation	3
To obtain permission to photograph or sketch	32
To submit objects for examination	173
To see members of the staff	376
To see the exhibition galleries on Mondays	49
To examine or purchase photographs	292

LECTURES AND DOCENT SERVICE

A 6 weeks' lecture course in Chinese and Japanese art was given by A. G. Wenley in the Far Eastern Institute held at the Harvard University Summer School of 1940 under the auspices of the American Council of Learned Societies.

At the Freer Gallery 6 illustrated lectures were given in the auditorium (total attendance, 98); 6 study groups were held in a study room (total attendance, 80); and 10 groups were given docent service in exhibition galleries (total attendance, 269). The total number of persons receiving instruction at their own request was 447.

PERSONNEL

February 13, 1941, William R. B. Acker returned from Holland, having taken his Ph. D. *cum laude* in Chinese at the University of Leyden.

September 3, 1940, Oliver W. Puckett reported for duty as watchman.

June 30, 1941, David H. Zirkle, watchman, who had been at the Gallery for 16 years, was retired with a record of the most faithful and efficient service.

October 10, 1940–June 18, 1941, Grace T. Whitney worked intermittently at the Gallery on the translation of Persian texts.

October 12, 1940, Elizabeth Hill, librarian, was married to Wilson R. Maltby, a physicist in the Naval Ordnance Laboratory at the U. S. Navy Yard.

Respectfully submitted.

J. E. LODGE, *Director*

Dr. C. G. ABBOT,
Secretary, Smithsonian Institution.

APPENDIX 5

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY

SIR: I have the honor to submit the following report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1941, conducted in accordance with the act of Congress of April 18, 1940, which provides "* * * for continuing ethnological researches among the American Indians and the natives of Hawaii and the excavation and preservation of archeologic remains. * * *"

SYSTEMATIC RESEARCHES

M. W. Stirling, Chief of the Bureau, left Washington on December 29 to continue his archeological excavations in southern Mexico. Intensive excavations were begun at the site of Cerro de las Mesas on the Rio Blanco in the state of Veracruz, this site having been visited the preceding season. In addition, another expedition was made to the site of Izapa in the southwestern part of the state of Chiapas. As in the 2 preceding years, the work was undertaken in cooperation with the National Geographic Society. Dr. Philip Drucker again accompanied Mr. Stirling as assistant archeologist.

At Cerro de las Mesas 20 carved stone monuments were unearthed and photographed, several mounds were cross-sectioned, and a number of stratigraphic trenches dug on various sections of the site. The stratigraphic work proved unusually successful and extends the cultural column for this part of Veracruz to a much later date than did the excavations at Tres Zapotes. Two initial series dates were deciphered at Cerro de las Mesas, one being in the 1st katun, the other in the 4th katun, of baktun 9. Another stone monument at this site was of considerable interest because of its similarity to the famous Tuxtla statuette. Large quantities of jade were found including one cache containing 782 specimens.

At Izapa a large number of stelae, most of them with altars, were excavated and photographed. This site is important because of its location, which makes it an interesting link between the west coast of Guatemala and the isthmian region of southern Mexico.

At the conclusion of the work at Cerro de las Mesas at the end of April, the collections were brought to Mexico City where Dr. Drucker remained to work with them.

During the year Dr. John R. Swanton, ethnologist, employed most of his time in completing an extensive report on the Indians of the Southeast, upon which work had been done during several past years, and which covers about 1,500 typewritten pages. This is now ready for final copy and editing.

The bulletin entitled "Source Material on the Ethnology and History of the Caddo Indians," upon which he was at work last year is now in galley proof. It will cover about 350 printed pages. A brief contribution by Dr. Swanton entitled "The Quipu and Peruvian Civilization" has been accepted for publication in a forthcoming bulletin of anthropological papers and is now in the hands of the printer.

Early in the year the bulletin prepared by Dr. Swanton entitled "Linguistic Material from the Tribes of Southern Texas and Northeastern Mexico," was completed and distributed. It contains all of the fragments of the Coahuiltecan, Karankawan, and Tamaulipecan tongues known to be in existence, and covers 145 pages.

Considerable time has also been devoted by Dr. Swanton to answering letters, including particularly extension of advice regarding the placing of markers along the route pursued by Hernando de Soto and work for the United States Board on Geographical Names.

At the beginning of the fiscal year Dr. John P. Harrington, ethnologist, was engaged in working over Navaho materials and those of the closely related Tlingit language of Alaska. Recent field studies had proved that something like 200 words of Navaho and Tlingit are almost the same despite the 2,000-mile separation of the two languages. Sometimes the same word was found to be applied to two very different organisms; for instance, what is crab apple in the north is cactus in the south (spininess being the trait which these two plants evidently have in common), and jack pine in the north was found to be juniper in the south.

Tlingit was copiously recorded in southeastern Alaska, and the Ugalenz language, related to the Tlingit and to the Navaho, was discovered and studied. The Ugalenz formerly occupied 350 miles of southeastern Alaska coast, from Prince William Sound in the west to Latuya Bay in the east.

The origin of the name Sitka, the old Russian capital of Alaska, was discovered. The name means "On the oceanward side of Baranov Island." Shee is the name of Baranov Island, and Sitka is situated on its oceanward side.

Leaving in August for Gallup, N. Mex., Dr. Harrington worked on many parts of the Navaho Reservation, finding a surprising uniformity in dialect. This uniformity must have arisen from a jumbling together of earlier Navaho dialects when the Navahos were in

captivity in eastern New Mexico in 1867 and 1868. During this captivity, dialects were evidently jostled together, and resettlement by the United States Government further dislocated them.

Field work during the latter part of the summer was done with more than 10 of the leading Navaho interpreters. In a tribe of more than 45,000 population, there are many educated speakers, including university graduates, and with them were explored special features of the language which could not have been obtained from the tongues of poor and uneducated tribes without much greater expenditure of time.

The Navaho language was found to have only 4 vowels and 34 consonants, making it a true consonantal language. The sounds of Navaho were found to be almost identical with those of the other languages of the Southwest, for instance, with those of the neighboring Tewa language. Also many words were found to be the same as in Tewa. Navaho was found to have, for practical purposes, a high and a low tone, and a falling and rising tone only on long vowels and diphthongs. One of the most peculiar developments to be found in any language is the hardening in Navaho of almost any consonant by placing a sound of German ch after it if it is voiceless, and of open g (gh) after it if it is voiced. There are also traces of a hardening of l to n, and the like.

Returning to Washington late in the fall, Dr. Harrington continued his study of the Navaho, until it now constitutes a finished manuscript of more than 1,200 pages. Throughout the work there has been a constant revelation that Navaho and related languages are not as unlike other American Indian languages as has been thought by early vocabulary makers and classifiers.

At the beginning of the fiscal year, July 1, 1940, Dr. Frank H. H. Roberts, Jr., was engaged in a continuation of excavations at the Lindenmeier site, a former Folsom camping ground, in northern Colorado. From August 1 to 31 he was on leave and during that period, in accord with the Smithsonian Institution's policy of cooperation with other scientific organizations, directed the excavation program of the advanced students at the University of New Mexico's Chaco Canyon Research Station.

From Chaco Canyon, N. Mex., Dr. Roberts went to Boulder City, Nev., to inspect a large cave located in the lower end of the Grand Canyon of the Colorado River at the upper reaches of Lake Mead. The trip to the cave was made by motorboat from Pierce's Ferry in company with officials of the National Park Service's Boulder Dam Recreational Area. Rampart Cave is situated in the south wall of the canyon at the top of a steep talus 600 feet above the present water level. It is of unusual interest because of its extensive deposits of

sloth remains and of the bones from large creatures that preyed on the sloth, and the possibility that it may provide evidence of human contemporaneity with such extinct animal forms in that area. Plans and methods for a program of excavation were discussed and various suggestions were made concerning the advisability of providing an exhibit in situ for visitors to the Boulder Dam Recreational Area.

From Boulder Dam, Dr. Roberts returned to the Lindenmeier site where he continued his investigations until the end of September when the project was brought to a close. During the six seasons of intensive exploration of this Folsom site and the adjacent area much new and valuable information on the subject of early occupation of North America was obtained. From the large series of specimens collected it will be possible to draw comprehensive conclusions relative to the material culture and economic status of the aboriginal peoples inhabiting that portion of the country during the closing days of the last Ice Age, and in general to broaden the knowledge on early stages in New World history.

Dr. Roberts returned to Washington in October. He spent the autumn and winter months working on the material from the Lindenmeier site, preparing the manuscript for his report on the investigations there, in writing short articles for publication in various scientific journals, in identifying numerous archeological specimens sent in from all parts of the country by interested amateurs, and in furnishing information on many phases of New World archeology. Plans and preparations were made for an expedition to the Coclé region in the province of Penonome, Panama, but, because of the last-minute development of an insuperable combination of adverse circumstances, the proposed investigations had to be abandoned.

On May 15, 1941, Dr. Roberts went to Bedford, Va., to initiate excavations at the Mons site near the Peaks of Otter where the late D. I. Bushnell, Jr., had found artifacts suggestive of a much earlier aboriginal occupation of the area than previously had been supposed. Construction work on the Blue Ridge Parkway had destroyed much of the site, but a series of test trenches dug in various undisturbed remnants established the fact that it had once been an Indian camping place, possibly a village site of late protohistoric times. However, there was no evidence of its having been used by older groups comparable to the early hunting peoples of the western plains.

On the completion of the work at the Mons site, Dr. Roberts returned to Washington and on June 11 left for San Jon, N. Mex. Camp was established on the rim of the Staked Plains 10½ miles south of that town and excavations were started at a site where material suggestive of another phase of early man in North America, the so-called Yuma, has been found. The location is in a shallow basin that appears to

have been an old, filled-in lake bed. Heavy erosion in recent years started a series of ravines and gullies and exposed extensive deposits of bones. Stone implements found near some of these outcroppings indicate the possibility that many of the creatures were killed by aboriginal hunters and that an association of man-made objects and bones from extinct species of animals can be established. Bison, camel, and mammoth bones, as well as those from smaller and as yet unidentified mammals, occur in the site. Material in the fill in the old lake bed probably can be correlated with other geologic phenomena of established age. Hence, the determination of contemporaneity between the artifacts, animal remains, and lake deposits would constitute an important addition to the evidence on early occupation in the New World. There is also a possibility that the site may contribute information on the subject of relationships between some of the different older cultural remains. At the close of the fiscal year Dr. Roberts and his party were well started on the problem of the San Jon site.

The beginning of the fiscal year found Dr. Julian H. Steward, anthropoligist, in British Columbia completing researches on aboriginal Carrier Indian ethnography and on ecological aspects of recent changes in Carrier socio-economic culture at Fort St. James and neighboring villages. While here a collection was made of more than 100 Carrier specimens of material culture, and of more than 50 ethnobotanical specimens. At this time several pit-lodge sites were examined. From here Dr. Steward proceeded to Alaska, and then by plane from Ketchikan to an island off the coast where he investigated a burial site reported by Commander F. A. Zeusler, of the Coast Guard, and Ranger Lloyd Bransford, of the United States Forest Service. Accompanied by the latter, he procured specimens of several skeletons, fragments of carved burial boxes and other materials, and a mummified body in excellent preservation. The body was dressed in buckskin, wrapped in a cedar mat, and deposited in a cedar box. All specimens were brought back by plane to Ketchikan and shipped to the Smithsonian Institution. From Alaska Dr. Steward went to Berkeley, Calif., to hold consultations on the Handbook of South American Indians, which is being prepared for the Smithsonian Institution. From there he proceeded to Albuquerque and Chaco Canyon, N. Mex., for further consultations and to attend the Coronado Quatrocentennial and the Chaco conference, finally arriving in Washington late in August.

The remainder of the year was devoted mainly to editorial and organizational work on the Handbook of South American Indians, and work on the project was actually initiated, $6,000 having been made available for this purpose by special appropriation for cooperation with the American republics through the Department of State's Inter-

departmental Committee. The collaboration of 33 contributors, each a specialist in some phase of South American anthropology, was arranged. Work accomplished during the year included completion of manuscripts by Dr. Robert H. Lowie and Dr. Alfred Métraux totaling more than 150,000 words; completion of a new base map drawn from the American Geographical Society's 1:1,000,000 sheets, and of four new maps showing respectively the vegetation, climates, physical features, and topography of South America; compilation of a preliminary bibliography of nearly 2,000 items; substantial progress on many other manuscripts; and integration of the Handbook plan with research activities of many other institutions in different countries. Arrangement was made to engage the services of Dr. Métraux on full-time basis as assistant editor in the fiscal year 1941–42. The services of a secretary were had for the Handbook during three months of 1941.

During the fall Dr. Steward acted as chairman of the Program Committee of the American Anthropological Association, arranging the program for the Christmas meetings in Philadelphia. He also served on the Committee on Latin American Anthropology of the National Research Council and accepted membership on the Scientific Advisory Committee of the Pan American Trade Committee.

The following scientific papers were published: Archeological Reconnaissance of Southern Utah, Bur. Amer. Ethnol. Bull. 128, pp. 275–356; Nevada Shoshone, in Univ. California Culture Element Distributions; several short papers on the Carrier Indians; a description of the Handbook of South American Indians for the Boletin Bibliografico de Antropología Americana. An article was prepared for American Antiquity on The Direct Historic Approach to Archeology.

During the fiscal year Dr. Henry B. Collins, Jr., ethnologist, continued with the study and description of archeological collections from prehistoric and protohistoric Eskimo village sites in the vicinity of Bering Strait. Material was also assembled for a paper on the origin and antiquity of the Eskimo race and culture in relation to the larger question of the original entry of man into America.

At the request of the Peabody Museum of American Archaeology and Ethnology of Harvard University, Dr. Collins made two trips to Cambridge to assist in the identification and selection of materials for the new Eskimo exhibit being planned by Donald Scott, director of the Museum, and his assistant, Frederick G. Pleasants.

Dr. Collins also served as collaborator and technical adviser for Erpi Classroom Films, Inc., in connection with production of a motion-picture record of Eskimo life on Nunivak Island, Alaska, to be made by Amos Burg, explorer and photographer. The film, designed for use in the elementary schools, will provide an authentic picture of the

daily life and activities of the Nunivagmiut, who have retained more of their native culture than any other coastal-group Eskimo in Alaska.

During July 1940 Dr. William N. Fenton, associate anthropologist, was engaged in field work among the Senecas of Allegany Reservation, N. Y. While here he delivered the St. Lawrence University series of lectures at the Allegany School of Natural History. The lectures on the Iroquoian Peoples of the Northeast covered prehistoric cultures of the area, the adjustment of the Iroquois to their environment, their society and government, and their religious system. At the Six Nations Reserve on Grand River, Ontario, Canada, August 9 to September 1, the yearly cycle of ceremonies that are currently celebrated at the Onondaga Longhouse were outlined by Simeon Gibson and the principal speeches that constitute the bulk of the annual Midwinter Festival were taken in Onondaga text and translated. This study is an extension of previous investigations of Seneca ceremonies which Dr. Fenton has published, and it adds new material on the nature of village bands and their removals, the function of moieties, the nature of residence after marriage, and the sororate which was practiced, at least by the Lower Cayugas. Further assistance was rendered by Deputy Chief Hardy Gibson with Hewitt's manuscript on the Requickening Address for installing chiefs in the Iroquois League, which Dr. Fenton is editing for publication.

Returning from the field September 15 with 300 photographic negatives, largely of masks studied at museums in New York and Ontario together with a series of their manufacture and use in Iroquois fraternities, much time elapsed assembling pictures and notes and arranging them for study.

A special paper on The Place of the Iroquois in the Prehistory of America was presented before the Anthropological Society of Washington; and Dr. Fenton also served as technical adviser for An Indian League of Nations, which was broadcast October 27 on "The World is Yours" radio program.

Work on two new research projects aimed at clearing up problems previously outlined was begun during the year. While serving as consultant to the Pennsylvania Historical Commission on archeological matters, Dr. Fenton contacted local historians who are collaborating in special phases of a study of Cornplanter's Senecas on the upper Allegheny River; and it is planned to publish their findings together with Quaker Mission Journals from 1798 which describe Indian life and events attending Handsome Lake's revelations. In quest of original sources, Dr. Fenton searched the Records of the Yearly Meeting of Friends of Philadelphia, and visited the libraries of Haverford and Swarthmore Colleges. In this project he has had the active help of M. E. Deardorff of Warren, Pa., and C. E.

Congdon of Salamanca, N. Y., who have located and transcribed other documentary sources.

Iroquois music has long deserved serious study, and with the development of modern electric sound-recording apparatus, record making in the field has become practicable. When the Division of Music in the Library of Congress furnished the necessary blanks and apparatus for Dr. Fenton's trip to the Six Nations Midwinter Festival, January 10 to February 17, 1941, Dr. Fenton undertook the task of making the recordings, first at Ohsweken, Ontario, and later at Quaker Ridge, N. Y. Sixty-two double-face records were made of samples of social and religious dance songs, and complete runs of several shamanistic song cycles and the Adoption Rite of the Tutelo were taken. Informants gave complete texts for all the recordings, and these, as rewritten after returning to Washington, should prove helpful to the transcriber. For this purpose the Recording Laboratory is furnishing a duplicate set. Because musicologists have expressed interest in the recordings, several were selected for a proposed Album of Iroquois Music, which the Library contemplates publishing; and in return for the fine cooperation of the Recording Laboratory and the Division of Music, Dr. Fenton delivered a lecture, Music in Iroquois Religion and Society, illustrated with slides and records, as the first of a series by the Archive of American Folk-song. It was repeated for the Society of Pennsylvania Archaeology at its annual meeting.

In addition a series of brief informal excursions were made to Allegany regarding place names and to explore the area that may be flooded by the proposed Allegheny Reservoir, and to Tonawanda to collect song texts of the Medicine Society.

Besides a number of book reviews in scientific and historical journals, Dr. Fenton published two papers in Bureau of American Ethnology Bulletin 128—Iroquois Suicide: A Study in the Stability of a Culture Pattern, and Tonawanda Longhouse Ceremonies: Ninety Years After Lewis Henry Morgan—and an article, Museum and Field Studies of Iroquois Masks and Ritualism, which appeared in the Explorations and Field-work of the Smithsonian Institution in 1940. Dr. Fenton prepared for publication in the Annual Report of the Smithsonian Institution for 1940, a paper entitled "Masked Medicine Societies of the Iroquois."

SPECIAL RESEARCHES

Miss Frances Densmore, a collaborator of the Bureau, continued her study of Indian music by collecting additional songs, transcribing these and songs previously recorded, and preparing material for publication. In August 1940 a trip was made to Wisconsin Dells, Wis.,

to interview a group of visiting Zuñi Indians. Songs were obtained from Falling Star, an Indian born in Zuñi, who had lived in the pueblo most of his life and taken part in the dances. His father also was a singer and dancer. Falling Star recorded 17 songs, 15 of which were transcribed and submitted to the Bureau. These are chiefly songs of lay-participants in the Rain Dance and the songs connected with grinding corn for household use.

Additional data on the peyote cult among the Winnebago were obtained from a former informant and incorporated in the manuscript on that tribe.

In October Miss Densmore went to Washington for consultation on manuscripts awaiting publication. During the winter she transcribed records of 71 Seminole songs, completing the transcriptions of recordings made in that tribe during the seasons of 1931, 1932, and 1933. It is expected that the book on Seminole music, containing 245 songs, will be completed in the near future.

A paper on A Search for Songs Among the Chitimacha Indians in Louisiana, submitted in 1933, was rewritten, amplified, and prepared for publication. The Chitimacha is the only tribe visited by Miss Densmore in which all the songs have been forgotten. Musical customs were remembered, and several legends were related in which songs were formerly sung.

In May 1941 Miss Densmore read a paper on The Native Art of the Chippewa before the Central States Branch of the American Anthropological Association at the Annual meeting held in Minneapolis.

At the close of the fiscal year Miss Densmore was in Nebraska, her special interest being a search for songs that were recorded phonographically by Miss Alice C. Fletcher in the decade prior to 1893 and published in that year by the Peabody Museum of American Archaeology and Ethnology. If Indians can be found who remember these songs, they will be recorded again. A comparison of the two recordings will show the degree of accuracy with which the songs have been transmitted, and will be important to the subject of Indian music.

The entire collection of recordings of Indian songs submitted to the Bureau by Miss Densmore has been transferred to the National Archives for permanent preservation. These recordings were made and submitted during the period from 1907 to 1940, all having been cataloged and transcribed in musical notation. Many hundreds of other recordings have been made, studied, and retained by Miss Densmore but not transcribed. Recordings submitted after 1940

have been cataloged in sequence with the former collection. Thirty-five tribes are represented in the collection of 2,237 recordings, in addition to a group of songs recorded in British Columbia in which the tribes are not designated.

EDITORIAL WORK AND PUBLICATIONS

The editorial work of the Bureau has continued during the year under the immediate direction of the editor, M. Helen Palmer. There were issued three bulletins, as follows:

Bulletin 126. Archeological remains in the Whitewater District, eastern Arizona. Part II. Artifacts and burials, by Frank H. H. Roberts, Jr. With appendix, Skeletal remains from the Whitewater District, eastern Arizona, by T. D. Stewart. xi+170 pp., 57 pls., 44 figs.

Bulletin 127. Linguistic material from the tribes of southern Texas and northeastern Mexico, by John R. Swanton. v+145 pp.

Bulletin 128. Anthropological papers, numbers 13–18. xii+368 pp., 52 pls., 77 figs.:

No. 13. The mining of gems and ornamental stones by American Indians, by Sydney H. Ball.

No. 14. Iroquois suicide: A study in the stability of a culture pattern, by William N. Fenton.

No. 15. Tonawanda Longhouse ceremonies: Ninety years after Lewis Henry Morgan, by William N. Fenton.

No. 16. The Quichua-speaking Indians of the Province of Imbabura (Ecuador) and their anthopometric relations with the living populations of the Andean area, by John Gillin.

No. 17. Art processes in birchbark of the River Desert Algonquin, a circumboreal trait, by Frank G. Speck.

No. 18. Archeological reconnaissance of southern Utah, by Julian H. Steward.

The following bulletins were in press at the close of the fiscal year:

Bulletin 129. An archeological survey of Pickwick Basin in the adjacent portions of the States of Alabama, Mississippi, and Tennessee, by William S. Webb and David L. De Jarnette. With additions by Walter P. Jones, J. P. E. Morrison, Marshall T. Newman and Charles E. Snow, and William G. Haag.

Bulletin 130. Archeological investigations at Buena Vista Lake, Kern County, California, by Waldo R. Wedel. With appendix, Skeletal remains from Buena Vista sites, California, by T. Dale Stewart.

Bulletin 131. Peachtree Mound and village site, Cherokee County, North Carolina, by Frank M. Setzler and Jesse D. Jennings. With appendix, Skeletal remains from the Peachtree Site, North Carolina, by T. Dale Stewart.

Bulletin 132. Source material on the history and ethnology of the Caddo Indians, by John R. Swanton.

Bulletin 133. Anthropological papers, numbers 19–26:

No. 19. A search for songs among the Chitimacha Indians in Louisiana, by Frances Densmore.

No. 20. Archeological survey on the northern Northwest Coast, by Philip Drucker.

No. 21. Some notes on a few sites in Beaufort County, South Carolina, by Regina Flannery.

No. 22. An analysis and interpretation of the ceramic remains from two sites near Beaufort, South Carolina, by James B. Griffin.

No. 23. The eastern Cherokees, by William Harlen Gilbert, Jr.

No. 24. Aconite poison whaling in Asia and America: An Aleutian transfer to the New World, by Robert F. Heizer.

No. 25. The Carrier Indians of the Buckley River: Their social and religious life, by Diamond Jenness.

No. 26. The Quipu and Peruvian civilization, by John R. Swanton.

Bulletin 134. Native tribes of eastern Bolivia and western Matto Grosso, by Alfred Métraux.

Publications distributed totaled 11,882.

LIBRARY

There has been no change in the library staff during the fiscal year. Accessions during the fiscal year totaled 378.

The library staff has relabeled and reshelved 5,137 books. The sections of general ethnology and non-American material, and linguistics have now been entirely reclassified and reshelved. Library of Congress printed cards, so far as they are available, have been ordered for practically all of this material, when not already in the catalog. Part of the work of typing these cards and filing in the catalog has been completed and will be finished in a month or two.

The sorting of foreign periodicals and society transactions has been completed and all material not in the library field has been put aside for appropriate disposal. A temporary shelf list has been made for this material and it is hoped that this section will be reclassified and reshelved by the first of the year. The checking lists for the second edition of the Union List of Serials were marked with our holdings and returned.

The sorting of the pamphlet collection has been completed and more than half have been classified and shelved. Library of Congress cards where available have been ordered. In the future the library will have no separate pamphlet collection. All pamphlets that are kept will be classified and shelved with the books. Work has also been done on Congressional documents and some of this material is now classified and reshelved. Government documents from the War and Interior Departments, publications of the Cherokee and Choctaw nations, and of various special boards and commissions have been sorted and classified and all Library of Congress cards available ordered.

ILLUSTRATIONS

Following is a summary of work accomplished during the fiscal year by Edwin G. Cassedy, illustrator:

Line drawings	602
Stipple drawings	3
Wash drawings	4
Maps	22
Graphs	6
Plates assembled	95
Photographs retouched	14
Lettering jobs	114
Mural paintings	2
Negatives retouched	5
Total	867

The month of December 1940 and the first half of January 1941 were devoted to work on the new Index Exhibit in the Smithsonian main hall.

COLLECTIONS

Collections transferred by the Bureau of American Ethnology to the Department of Anthropology, United States National Museum, during the fiscal year were as follows:

Accession No.

124,559. Portions of a child's skull and skeleton collected near Kissimmee, Fla., and sent in by L. R. Farmer.

157,350. Skeletal and cultural remains from burial sites on Pennock Island and Dall Island, southeastern Alaska, collected during the summer of 1940 by Dr. Julian H. Steward. (36 specimens.)

157,796. Collection of 94 ethnological specimens from the Carrier Indians, obtained by Dr. Julian H. Steward in the region of Fort St. James, British Columbia, in 1940.

157,965. Collection of ethnological objects purchased among the Iroquois Indians during the past summer by Dr. William N. Fenton. (3 specimens.)

158,151. Collection of carved wooden masks and musical instruments collected by the late J. N. B. Hewitt among the Iroquois Indians of the Six Nations Reserve, Grand River, Ontario, Canada. (27 specimens.)

158,498. Two unfinished wooden masks made by Tom Harris, an Onondaga Indian of the Six Nations Reserve, Grand River, Ontario, Canada, and collected in August 1940 by Dr. William N. Fenton.

160,243. Archeological specimens from a sand burial mound on Lemon Bay, near Englewood, Sarasota Co., Fla. (25 specimens.)

160,244. Archeological specimens from various mounds in the vicinity of Parrish, on Little Manatee River, Manatee Co., Fla. (61 specimens.)

160,249. Archeological and skeletal material from a refuse and burial mound 1½ miles west of Belle Glade, in Palm Beach Co., Fla. (988 archeological specimens. The skeletal material in this accession has not been counted this year, but the figures will be included in some future annual report.)

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MISCELLANEOUS

During the course of the year information was furnished by members of the Bureau staff in reply to numerous inquiries concerning the North American Indians, both past and present, and the Mexican peoples of the prehistoric and early historic periods. Various specimens sent to the Bureau were identified and data on them furnished for their owners.

Personnel.—Mrs. Frances S. Nichols, editorial assistant, retired on August 31, 1940; Miss Anna M. Link served as editorial assistant from September 1, 1940, to April 30, 1941, when she resigned to accept a position in the library of the United States National Museum; Miss Nancy A. Link was appointed on June 1, 1941, to fill this vacancy. Miss Florence G. Schwindler was appointed on January 6, 1941, as stenographer in connection with the preparation of the Handbook of South American Indians; she resigned on April 21, 1941, to accept a position in the War Department.

Respectfully submitted.

M. W. STIRLING, *Chief.*

DR. C. G. ABBOT,
Secretary, Smithsonian Institution.

APPENDIX 6

REPORT ON THE INTERNATIONAL EXCHANGE SERVICE

SIR: I have the honor to submit the following report on the activities of the International Exchange Service during the fiscal year ended June 30, 1941:

The appropriation allowed by Congress was $44,880, the same amount as for the previous year. There was also received by transfer from the Department of State $500 from an appropriation made by Congress to that Department for cooperation with the American republics. This amount was allotted to the Exchange Service for mailing packages of publications to the Argentine Republic and Brazil, so that they would reach their destinations without the delay which occurs when shipments are made through exchange bureaus. To all other South and Central American countries, with one exception, exchanges are transmitted by mail under governmental frank. From repayments there was collected $3,036.53, making the total available resources $48,416.53.

The number of packages received for transmission during the year was 576,282, a decrease of 63,062. The weight was 388,649 pounds, a decrease of 138,896 pounds.

The following table gives the number and weight of packages sent and received through the service:

	Packages		Weight	
	Sent abroad	Received from abroad	Sent abroad	Received from abroad
			Pounds	*Pounds*
United States parliamentary documents sent abroad	349,021		136,717	
Publications received in return for parliamentary documents		1,354		4,549
United States departmental documents sent abroad	103,552		99,731	
Publications received in return for departmental documents		3,044		6,093
Miscellaneous scientific and literary publications sent abroad	92,196		116,897	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States		27,115		24,662
Total	544,769	31,513	353,345	35,304
Grand total	576,282		388,649	

The packages referred to in the above table as sent abroad were forwarded partly in boxes by freight to exchange bureaus for dis-

tribution and partly by mail directly to their destinations. The number of boxes shipped was 965, a decrease from the preceding year of 929. Of these boxes, 419 were for depositories of full sets of United States governmental documents and the contents of the remainder were for depositories of partial sets and for distribution to various establishments and individuals. The number of mail packages was 117,700.

As stated last year, when a decrease in the work of the office was reported, the falling off in the amount of material handled is due to the interruption of the interchange of publications between the United States and many countries owing to the foreign wars. Shipments to nearly all the European countries, as well as to China and places bordering on the Mediterranean, have been suspended temporarily. Through special efforts, however, it has been possible during the latter part of the year to forward large consignments to Sweden and Switzerland. Transmissions were made to Finland and the Soviet Republic almost to the end of the fiscal year, but when those countries became involved in the European war, further shipments to them were suspended. One large consignment was forwarded to Spain during the year and several others were sent to Portugal. Owing to the conditions abroad, however, the Institution cannot follow any regular schedule in the sending of boxes to those two countries. With the exception of one or two short suspensions, there has been no interruption to the transmission of shipments to and from Great Britain, although, owing to the shortage of cargo space, it has not been possible to dispatch consignments as promptly as before the war.

The British Museum and the London School of Economics and Political Science, both depositories of United States governmental documents, have requested that no further consignments be forwarded to them until the close of the war, because of the possibility of destruction of the material through the bombings of London. The Edinburgh Public Library and the St. Andrews University also have asked that publications for them be stored until the cessation of hostilities. No other requests for the withholding of transmissions have been made by British establishments.

The very large number of packages for shipment abroad that are being held here awaiting the cessation of the war has overtaxed the space in the Exchange rooms to such an extent that it has been necessary to construct a storage shed in the grounds in the rear of the Smithsonian Building for storing the books. The structure is made of corrugated iron and is substantially built. When the emergency is over, the shed will be used for the storage of empty packing boxes.

Since the outbreak of the European war in September 1939, so far as reported to the Institution, five consignments of exchanges have been lost, the details of which are given below:

Five boxes forwarded to Denmark in December 1939 were destroyed on the dock in Bergen by fire caused by airplane bombardment.

Five boxes sent to France in April 1940 were destroyed by fire at the Havre railroad station.

Eleven boxes forwarded to England in November 1940 were lost at sea.

Thirteen boxes sent to Germany in August 1939 were lost at Havre after the consignment was disembarked.

One box, while in the warehouse of the Smithsonian agents in London awaiting shipment to the Institution, was destroyed in January 1941 by fire caused by airplane bombardment.

FOREIGN DEPOSITORIES OF GOVERNMENTAL DOCUMENTS

On account of conditions in Europe due to the war, several depositories have been removed from the list of those receiving full and partial sets of United States governmental documents. This has resulted in reducing the number of those publications now received from a total of 104 to 92—55 full and 37 partial sets.

The depository of the partial set in Haiti has been changed from the Department of Foreign Affairs to the National Library. The Honduran Ministry of Foreign Affairs has been added to the partial-set list.

A complete list of the depositories is given below:

DEPOSITORIES OF FULL SETS

ARGENTINA: Dirección de Investigaciones, Archivo y Propaganda, Ministerio de Relaciones Exteriores y Culto, Buenos Aires.

AUSTRALIA: Commonwealth Parliament and National Library, Canberra.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

QUEENSLAND: Parliamentary Library, Brisbane.

SOUTH AUSTRALIA: Parliamentary Library, Adelaide.

TASMANIA: Parliamentary Library, Hobart.

VICTORIA: Public Library of Victoria, Melbourne.

WESTERN AUSTRALIA: Public Library of Western Australia, Perth.

BELGIUM: Bibliothèque Royale, Bruxelles.

BRAZIL: Instituto Nacional do Livro, Rio de Janeiro.

CANADA: Library of Parliament, Ottawa.

MANITOBA: Provincial Library, Winnipeg.

ONTARIO: Legislative Library, Toronto.

QUEBEC: Library of the Legislature of the Province of Quebec.

CHILE: Biblioteca Nacional, Santiago.

CHINA: Bureau of International Exchange, Ministry of Education, Chungking.

COLOMBIA: Biblioteca Nacional, Bogotá.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

CUBA: Ministerio de Estado, Dirección de Relaciones Culturales, Habana.

CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.

DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.
EGYPT: Bureau des Publications, Ministère des Finances, Cairo.
ESTONIA: Riigiraamatukogu (State Library), Tallinn.
FINLAND: Parliamentary Library, Helsinki.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Reichstauschstelle im Reichsministerium für Wissenschaft, Erziehung und Volksbildung, Berlin, N. W. 7.
PRUSSIA: Preussische Staatsbibliothek, Berlin, N. W. 7.
GREAT BRITAIN:
ENGLAND: British Museum, London.
LONDON: London School of Economics and Political Science. (Depository of the London County Council.)
HUNGARY: Library, Hungarian House of Delegates, Budapest.
INDIA: Imperial Library, Calcutta.
IRELAND: National Library of Ireland, Dublin.
ITALY: Ministero dell'Educazione Nazionale, Rome.
JAPAN: Imperial Library of Japan, Tokyo.
LATVIA: Bibliothèque d'État, Riga.
LEAGUE OF NATIONS: Library of the League of Nations, Geneva, Switzerland.
MEXICO: Dirección General de Información, Mexico, D. F.
NETHERLANDS: Royal Library, The Hague.
NEW ZEALAND: General Assembly Library, Wellington.
NORTHERN IRELAND: H. M. Stationery Office, Belfast.
NORWAY: Universitets-Bibliothek, Oslo. (Depository of the Government of Norway.)
PERU: Sección de Propaganda y Publicaciones, Ministerio de Relaciones Exteriores, Lima.
POLAND: Bibliothèque Nationale, Warsaw.
PORTUGAL: Bibliotheca Nacional, Lisbon.
RUMANIA: Academia Română, Bucharest.
SPAIN: Cambio Internacional de Publicaciones, Avenida de Calvo Sotelo 20, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.
TURKEY: Department of Printing and Engraving, Ministry of Education, Istanbul.
UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
UNION OF SOVIET SOCIALIST REPUBLICS: All-Union Lenin Library, Moscow 115.
UKRAINE: Ukrainian Society for Cultural Relations with Foreign Countries, Kiev.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
YUGOSLAVIA: Ministère de l'Education, Belgrade.

DEPOSITORIES OF PARTIAL SETS

AFGHANISTAN: Ministry of Foreign Affairs, Publications Department, Kabul.
BOLIVIA: Biblioteca del H. Congreso Nacional, La Paz.
BRAZIL:
MINAS GERAES: Directoria Geral de Estatistica em Minas, Bello Horizonte.
RIO DE JANEIRO: Bibliotheca da Assemblea Legislativa do Estado, Nictheroy.
BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.

CANADA:
ALBERTA: Provincial Library, Edmonton.
BRITISH COLUMBIA: Provincial Library, Victoria.
NEW BRUNSWICK: Legislative Library, Fredericton.
NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.
PRINCE EDWARD ISLAND: Legislative and Public Library, Charlottetown.
SASKATCHEWAN: Legislative Library, Regina.
CEYLON: Chief Secretary's Office (Record Department of the Library), Colombo.
CHINA: National Library of Peiping.
DOMINICAN REPUBLIC: Biblioteca del Senado, Ciudad Trujillo.
ECUADOR: Biblioteca Nacional, Quito.
GUATEMALA: Biblioteca Nacional, Guatemala.
HAITI: Bibliothèque Nationale. Port-au-Prince.
HONDURAS:
Biblioteca y Archivo Nacionales, Tegucigalpa.
Ministerio de Relaciones Exteriores, Tegucigalpa.
ICELAND: National Library, Reykjavik.
INDIA:
BENGAL: Secretary, Bengal Legislative Council Department, Council House, Calcutta.
BIHAR AND ORISSA: Revenue Department, Patna.
BOMBAY: Undersecretary to the Government of Bombay, General Department, Bombay.
BURMA: Secretary to the Government of Burma, Education Department, Rangoon.
PUNJAB: Chief Secretary to the Government of the Punjab, Lahore.
UNITED PROVINCES OF AGRA AND OUDH: University of Allahabad, Allahabad.
JAMAICA: Colonial Secretary, Kingston.
LIBERIA: Department of State, Monrovia.
MALTA: Minister for the Treasury, Valletta.
NEWFOUNDLAND: Department of Home Affairs, St. John's.
NICARAGUA: Ministerio de Relaciones Exteriores, Managua.
PANAMA: Secretaría de Relaciones Exteriores, Panama.
PARAGUAY: Secretario de la Presidencia de la República, Asunción.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
STRAITS SETTLEMENTS: Colonial Secretary, Singapore.
THAILAND: Department of Foreign Affairs, Bangkok.
VATICAN CITY: Biblioteca Apostolica Vaticana, Vatican City, Italy.

INTERPARLIAMENTARY EXCHANGE OF THE OFFICIAL JOURNAL

On account of conditions arising from the war, the sending of the Congressional Record and the Federal Register has been discontinued to certain countries. Haiti has been added to the list as a recipient. The number of copies of the Record and the Register now sent abroad is 78, having been reduced from 104. A list of the present depositories is given below:

DEPOSITORIES OF CONGRESSIONAL RECORD

ARGENTINA:
Biblioteca del Congreso Nacional, Buenos Aires.
Cámara de Diputados, Oficina de Información Parlamentaria, Buenos Aires.
Boletín Oficial de la República Argentina, Ministerio de Justicia e Instrucción Pública, Buenos Aires.

AUSTRALIA:
Library of the Commonwealth Parliament, Canberra.
NEW SOUTH WALES: Library of Parliament of New South Wales, Sydney.
QUEENSLAND: Chief Secretary's Office, Brisbane.
WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.
BRAZIL:
Bibliotheca do Congresso Nacional, Rio de Janeiro.
AMAZONAS: Archivo, Bibliotheca e Imprensa Publica, Manáos.
BAHIA: Governador do Estado da Bahia, São Salvador.
ESPIRITO SANTO: Presidencia do Estado do Espirito Santo, Victoria.
RIO GRANDE DO SUL: "A Federação," Porto Alegre.
SÃO PAULO: Diario Official do Estado de São Paulo, São Paulo.
SERGIPE: Bibliotheca Publica do Estado de Sergipe, Aracajú.
BRITISH HONDURAS: Colonial Secretary, Belize.
CANADA:
Clerk of the Senate, Houses of Parliament, Ottawa.
Library of Parliament, Ottawa.
CUBA: Biblioteca del Capitolio, Habana.
EGYPT:
Chambre des Députés, Cairo.
Sénat, Cairo.
GIBRALTAR: Gibraltar Garrison Library Committee, Gibraltar.
GREAT BRITAIN: Library of the Foreign Office, London.
GUATEMALA: Biblioteca de la Asamblea Legislativa, Guatemala.
HAITI: Bibliothéque Nationale, Port-au-Prince.
HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.
HUNGARY: A Magyar országgyülés könyvtará, Budapest.
INDIA: Legislative Department, Simla.
INDOCHINA: Gouverneur Général de l'Indochine, Hanoi.
IRAN: Library of the Iranian Parliament, Téhéran.
IRAQ: Chamber of Deputies, Baghdad.
IRISH FREE STATE: Dail Eireann, Dublin.
LEAGUE OF NATIONS: Library of the League of Nations, Geneva, Switzerland.
LEBANON: Ministère des Finances de la République Libanaise, Service du Matériel, Beirut.
LIBERIA: Department of State, Monrovia.
MEXICO: Dirección General de Información, Mexico, D. F.
AGUASCALIENTES: Gobernador del Estado de Aguascalientes, Aguascalientes.
CAMPECHE: Gobernador del Estado de Campeche, Campeche.
CHIAPAS: Gobernador del Estado de Chiapas, Tuxtla Gutierrez.
CHIHUAHUA: Gobernador del Estado de Chihuahua, Chihuahua.
COAHUILA: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.
COLIMA: Gobernador del Estado de Colima, Colima.
DURANGO: Gobernador Constitucional del Estado de Durango, Durango.
GUANAJUATO: Secretaría General de Gobierno del Estado, Guanajuato.
GUERRERO: Gobernador del Estado de Guerrero, Chilpancingo.
JALISCO: Biblioteca del Estado, Guadalajara.
LOWER CALIFORNIA: Gobernador del Distrito Norte, Mexicali.
MÉXICO: Gaceta del Gobierno, Toluca.
MICHOACÁN: Secretaría General de Gobierno del Estado de Michoacán, Morelia.
MORELOS: Palacio de Gobierno, Cuernavaca.

MEXICO—Continued.
NAYARIT: Gobernador de Nayarit, Tepic.
NUEVO LEÓN: Biblioteca del Estado, Monterrey.
OAXACA: Periódico Oficial, Palacio de Gobierno, Oaxaca.
PUEBLA: Secretaría General de Gobierno, Puebla.
QUERÉTARO: Secretaría General de Gobierno, Sección de Archivo, Querétaro.
SAN LUIS POTOSÍ: Congreso del Estado, San Luis Potosí.
SINALOA: Gobernador del Estado de Sinaloa, Culiacán.
SONORA: Gobernador del Estado de Sonora, Hermosillo.
TABASCO: Secretaría General de Gobierno, Sección 3a, Ramo de Prensa, Villahermosa.
TAMAULIPAS: Secretaría General de Gobierno, Victoria.
TLAXCALA: Secretaría de Gobierno del Estado, Tlaxcala.
VERACRUZ: Gobernador del Estado de Veracruz, Departamento de Gobernación y Justicia, Jalapa.
YUCATÁN: Gobernador del Estado de Yucatán, Mérida, Yucatán.
NETHERLANDS INDIES: Volksraad von Nederlandsch-Indië, Batavia, Java.
NEW ZEALAND: General Assembly Library, Wellington.
PERU: Cámara de Diputados, Lima.
RUMANIA:
Bibliothèque de la Chambre des Députés, Bucharest.
Ministère des Affaires Étrangères, Bucharest.
SWITZERLAND: Bibliothèque de l'Assemblée Fédérale Suisse, Berne.
BERN: Staatskanzlei des Kantons Bern.
ST. GALLEN: Staatskanzlei des Kantons St. Gallen.
SCHAFFHAUSEN: Staatskanzlei des Kantons Schaffhausen.
ZÜRICH: Staatskanzlei des Kantons Zürich.
TURKEY: Turkish Grand National Assembly, Ankara.
UNION OF SOUTH AFRICA:
Library of Parliament, Cape Town, Cape of Good Hope.
State Library, Pretoria, Transvaal.
URUGUAY: Diario Oficial, Calle Florida 1178, Montevideo.
VENEZUELA: Biblioteca del Congreso, Caracas.
VATICAN CITY: Biblioteca Apostolica Vaticana, Vatican City, Italy.

FOREIGN EXCHANGE AGENCIES

The bureaus or agencies to which consignments are forwarded in boxes by freight are given below. To all countries not appearing in the list, packages are sent directly to their destinations by mail.

LIST OF AGENCIES

ALGERIA, via France.
ANGOLA, via Portugal.
AUSTRIA, via Germany.
AZORES, via Portugal.
BELGIUM: Service Belge des Échanges Internationaux, Bibliothèque Royale de Belgique, Bruxelles.
CANARY ISLANDS, via Spain.
CHINA: Bureau of International Exchange, Ministry of Education, Chungking.
CZECHOSLOVAKIA: Service des Échanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1–79.
DENMARK: Service Danois des Échanges Internationaux, Kongelige Danske Videnskabernes Selskab, Copenhagen V.

EGYPT: Government Press, Publications Office, Bulaq, Cairo.
FINLAND: Delegation of the Scientific Societies of Finland, Kasärngatan 24, Helsinki.
FRANCE: Service Français des Échanges Internationaux, 110 Rue de Grenelle, Paris.
GERMANY: Amerika-Institut, Universitätstrasse 8, Berlin, N. W. 7.
GREAT BRITAIN AND IRELAND: Wheldon & Wesley, 721 North Circular Road, Willesden, London, NW. 2.
HUNGARY: Hungarian Libraries Board, Ferenciektere 5, Budapest, IV.
INDIA: Superintendent of Government Printing and Stationery, Bombay.
ITALY: Ufficio degli Scambi Internazionali, Ministero dell'Educazione Nazionale, Rome.
JAPAN: International Exchange Service, Imperial Library of Japan, Uyeno Park, Tokyo.
LATVIA: Service des Échanges Internationaux, Bibliothèque d'Etat de Lettonie, Riga.
LUXEMBOURG, via Belgium.
MADAGASCAR, via France.
MADEIRA, via Portugal.
MOZAMBIQUE, via Portugal.
NETHERLANDS: International Exchange Bureau of the Netherlands, Royal Library, The Hague.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
NEW ZEALAND: General Assembly Library, Wellington.
NORWAY: Service Norvégien des Échanges Internationaux, Bibliothèque de l'Université Royale, Oslo.
PALESTINE: Jewish National and University Library, Jerusalem.
POLAND: Service Polonais des Échanges Internationaux, Bibliothèque Nationale, Warsaw.
PORTUGAL: Secção de Trocas Internacionaes, Bibliotheca Nacional, Lisbon.
QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.
RUMANIA: Ministère de la Propagande Nationale, Service des Échanges Internationaux, Bucharest.
SOUTH AUSTRALIA: South Australian Government Exchanges Bureau, Government Printing and Stationery Office, Adelaide.
SPAIN: Junta de Intercambio y Adquisición de Libros y Revistas para Bibliotecas Públicas, Ministerio de Educación Nacional, Avenida Calvo Sotelo, 20, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Berne.
TASMANIA: Secretary to the Premier, Hobart.
TURKEY: Ministry of Education, Department of Printing and Engraving, Istanbul.
UNION OF SOUTH AFRICA: Government Printing and Stationery Office, Capetown, Cape of Good Hope.
UNION OF SOVIET SOCIALIST REPUBLICS: International Book Exchange Department, Society for Cultural Relations with Foreign Countries, Moscow, 56.
VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
YUGOSLAVIA: Section des Échanges Internationaux, Ministère des Affaires Étrangères, Belgrade.

After the expiration of the year's extension granted Frank E. Gass, he was retired from the Government service February 28, 1941. However, having been appointed correspondence clerk on the Smithsonian private roll, effective March 1, he is continuing to carry on his work in the Exchange office.

Respectfully submitted.

C. W. SHOEMAKER, *Chief Clerk.*

Dr. C. G. ABBOT,
Secretary, Smithsonian Institution.

APPENDIX 7

REPORT ON THE NATIONAL ZOOLOGICAL PARK

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ended June 30, 1941:

The regular appropriation made by Congress was $239,910, all of which was expended with the exception of $2,440 which represents savings from lapses in the filling of vacant positions.

PERSONNEL

An important personnel change was the appointment on June 2, 1941, of Carter H. Anthony, D. V. M., as veterinarian. He came to the Zoo from the University of Arkansas, where he was engaged in animal disease research work. This is the first time in the history of the Zoo that a full-time position of this character has been filled. It is expected that this will result in a more careful dietary supervision, as well as much better medical and surgical attendance on the animals. Also closer cooperation can be given the various Government departments, as well as outsiders, in any experiments and studies in which the facilities of the Zoo are used.

A much larger turnover in the force than in prior years has been occasioned by men accepting positions in work connected with the National Defense program. Included in this was the recall to active service of William J. Grant, senior operating engineer, a member of the Naval Reserve.

IMPROVEMENTS

The closing of the W. P. A. project at the Zoo on August 6, 1940, prevented improvements that had been contemplated for the year. The regular force is hardly sufficient to maintain routine repairs, and therefore few improvements were begun.

The series of four waterfowl ponds was completed, and birds transferred there on July 29, 1940. This now makes one of the most attractive outdoor exhibits in the Zoo. It is especially so when viewed from the terrace of the new restaurant.

The reptile pit on the south side of the reptile house was completed by adding a small waterfall at one corner.



1. DINING ROOM, NEW RESTAURANT, NATIONAL ZOOLOGICAL PARK.



2 BIRDS IN THE REFRIGERATED CAGE NATIONAL ZOOLOGICAL PARK

The five birds are those received from Antarctic Service Expedition, 1941. The three large penguins right foreground, are emperors; the one to the left is a gentoo penguin; rear center, a kelp gull.

The old waterfowl pond near the creek was filled in with earth and crushed rock, though no grading was done. Some planting was done in that area. It is planned to utilize this space for parking of cars and also to make part of it available for picnicking.

Work was begun on remodeling the west side of the antelope building, and at the close of the year it was about two-thirds completed. A cage is being constructed to house the pair of reticulated giraffe. This will give them a cage with a higher ceiling as well as a larger outdoor enclosure.

The restaurant constructed by the P. W. A. under an allotment of $90,000 was completed in the fall of 1940. It is of the Virginia tavern type of stone construction. The main dining room is beautifully decorated with murals of carved lacquered linoleum, executed and mounted by Domenico Mortellito. This, with the outside terraces overlooking the new waterfowl ponds, has proved to be a popular luncheon and dining place for the public. The new concessionaire, L. G. Leech, opened the restaurant for business on March 29, 1941.

The area about the new restaurant was landscaped with evergreens and other trees and shrubs. An azalea garden of about 300 plants was laid out on the hillside west of the restaurant. This will greatly add to the beauty of the surroundings, especially when the plants are in bloom. In addition, about 200 wild azaleas, more than 100 dogwoods, and about 40 redbuds, as well as other trees and shrubs, were planted about the grounds.

It is with pleasure that we take this opportunity to thank C. A. Logan, of the Beltsville Agriculture Center, for the more than 350 trees and shrubs that were obtained from their C. C. C. nursery. These included shade trees, flowering plants and shrubs, fruit- and nut-bearing types, and others suitable for ornamental purposes.

NEEDS OF THE ZOO

Proper buildings continue to be the chief need of the Zoo. Structures most urgently needed which would complete its development are a new building to house antelope, deer, wild hogs, and kangaroos; one for monkeys; and one for carnivores to replace the present building, which is no longer suitable for the exhibition of these animals.

Since the closing of the W. P. A. project, and with the increase of exhibition areas, the existing personnel is inadequate to maintain the grounds in a presentable condition. It is therefore important that the maintenance personnel be increased by at least 10 men.

VISITORS FOR THE YEAR

A record of the attendance for the year shows an increase of a little more than 300,000 visitors over the figures for last year. This is due in part to the increase in population in the city.

July	221,700	February	95,800
August	216,300	March	171,700
September	315,500	April	265,000
October	166,200	May	277,800
November	169,900	June	280,100
December	134,700		
January	115,600	Total	2,430,300

The attendance of organizations, mainly classes of students, of which there is definite record, was 48,050, from 876 different schools or groups in 20 States and the District of Columbia. This is the largest number of such groups ever recorded. A complete listing by States follows:

State	Number of persons	Number of parties	State	Number of persons	Number of parties
Connecticut	413	7	New Jersey	2,365	33
Delaware	526	12	New York	964	23
District of Columbia	8,115	142	North Carolina	1,457	39
Georgia	516	15	Ohio	1,256	33
Illinois	38	1	Pennsylvania	10,304	201
Indiana	31	1	South Carolina	1,474	38
Kentucky	128	4	Tennessee	135	4
Maine	100	2	Virginia	7,563	139
Maryland	9,708	130	West Virginia	2,309	38
Massachusetts	152	3			
Michigan	375	9			
New Hampshire	121	2	Total	48,050	876

About 3 o'clock every afternoon, a census is made of the cars parked on the Zoo grounds. During the year 56,185 were so listed, representing every State in the Union, as well as Alaska, Canada, Canal Zone, Cuba, Hawaii, Mexico, and the Philippine Islands.

Since the total number is merely a record of those actually parked at one time, it is not of value as showing a total attendance, but is of importance as indicating the percentage of attendance by States, Territories, and countries. The record for the year on this basis shows the District of Columbia automobiles comprised 38 percent; Maryland, slightly more than 24 percent; Virginia, 16 percent; Pennsylvania, 4 percent; and the remaining cars were from other States, Territories, and countries.

This is the first year that the cars were counted on Sundays and holidays. In previous years, the record showed that a little more than 50 percent of the cars were from outside the District. This year it is 62 percent, which substantiates our estimate of previous years that adding Sundays and holidays to the count would show at least 60 percent from outside the District.

ACCESSIONS

FIELD WORK

SMITHSONIAN-FIRESTONE EXPEDITION

A partial account of this expedition was given in the 1940 annual report of the Director of the National Zoological Park.

Through funds donated to the Smithsonian Institution by the Firestone Tire & Rubber Co., of Akron, Ohio, a party was sent to Liberia, West Africa, for the purpose of collecting specimens for the National Zoological Park. The party consisted of the Director, Mrs. Mann, Ralph Norris, and Roy J. Jennier. They sailed on the American-West African Line on February 17, 1940, for Monrovia.

A preliminary shipment of animals collected was made from Liberia to Boston in the care of Roy J. Jennier, who arrived at that port on May 17, 1940. A list of these animals can be found in the 1940 annual report. The remaining members of the expedition arrived in Norfolk, Va., on August 6, 1940, with 100 specimens, several of which were species new to the history of the collection. We again wish to express our sincerest appreciation to the members of the Firestone staff, both in Liberia and here, for the aid and hospitality given the expedition.

A list of the live animals which arrived in Norfolk on August 6 follows:

SMITHSONIAN-FIRESTONE EXPEDITION

Scientific name	*Common name*	*Number*
Civettictis civetta	African civet	2
Genetta poensis	Dark genet	2
Nandinia binotata	African palm civet	1
Galerella melanura	Dwarf civet	1
Perodicticus potto	Potto	1
Cercocebus torquatus lunulatus	White-crowned mangabey	1
Cercocebus sp	Mangabey	6
Mandrillus sp	Mandrill	1
Papio papio	Baboon	1
Euxerus erythropus lacustris	African ground squirrel	2
Mellivora capensis	Ratel	1
Cricetomys gambianus liberiae	Liberian giant pouched rat	2
Choeropsis liberiensis	Pigmy hippopotamus	2
Atherura africana	West African brush-tailed porcupine	1
Hyemoschus aquaticus	Chevrotain	4
Cephalophus niger	Black duiker	3
Cephalophus nigrifrons	Black-fronted duiker	3

SMITHSONIAN-FIRESTONE EXPEDITION—continued

Scientific name	*Common name*	*Number*
Crossarchus obscurus	Marsh civet	1
Psittacus erithacus	African gray parrot	2
Agapornis pullaria	Red-faced lovebird	19
Ceratogymna elata	Yellow-casqued hornbill	1
Stephanoaetus coronatus	Crowned hawk-eagle	2
Gypohierax angolensis	Fish-eating vulture	1
Kaupifalco monogrammicus	Northern lizard-buzzard	1
Accipiter tachiro macroscelides	West African goshawk	1
Bitis nasicornis	Rhinoceros viper	3
Bitis gabonica	Gaboon viper	2
Naja sp	Cobra	2
Python sebae	West African python	2
Varanus niloticus	Nile monitor	4
Hyperolius sp	West African tree frog	11
Rana occipitalis	West African bullfrog	4
Osteolaemus tetraspis	Broad-nosed crocodile	1
Crocodylus cataphractus	Narrow-nosed crocodile	1
Kinixys erosa	West African back-hinged tortoise	7
Pelusios derbianus	Turtle	1

A summary of the specimens received from the expedition, including those in both shipments, follows:

Class	*Species*	*Individuals*
Mammals	23	48
Birds	15	42
Reptiles	20	76
Amphibians	2	15
Mollusks	1	14
Total	61	195

GIFTS

Pleasant contacts made by two previous expeditions have resulted in the receipt as gifts of a number of desirable specimens.

From the Firestone Plantation in Liberia, through George Seybold, manager, and Dr. Fuszek, Director General of Public Health of Liberia, the Zoo received a pigmy hippo, a western chimpanzee, a leopard, 2 rhinoceros vipers, a green mamba, a crowned hawk-eagle, and a porcupine. These resulted from associations made during the Smithsonian-Firestone expedition of 1940.

Through contacts made by Malcolm Davis, Zoo staff member of the Antarctic expedition of 1940, an interesting lot of birds was received, including 3 emperor penguins, 4 Gentoo penguins, 2 kelp gulls, and a giant fulmar. These birds were collected through the cooperation of Richard Black, Dr. Paul Siple, Jack Perkins, Roger Hawthorne, and others of the expedition, and brought to the States by Herwil Bryant, Jr., whose painstaking care on the trip saved

all the specimens. Other outstanding gifts include a pair of black bear cubs from Newbold Noyes, Washington, D. C., an ocelot each from Maj. C. V. Haynes, Langley Field, Va., and N. M. Rhodes, U. S. Naval Academy, Annapolis, Md., and a trio of tahr goats from the New York Zoological Park. E. A. McIlhenny, of Avery Island, La., has continued his generosity by sending a number of waterfowl, greatly adding to the exhibition value of the new waterfowl ponds. A complete list of donors and their gifts follows.

DONORS AND THEIR GIFTS

Mrs. Robert Adams, Washington, D. C., 2 opossums.
Mrs. Reed Alexander, Washington, D. C., Virginia rail.
Richard Archbold, American Museum of Natural History, New York, 2 ringtails or cacomistles.
S. D. Ashford, Washington, D. C., opossum.
Mrs. J. K. Atherton, Hyattsville, Md., double yellow-head parrot.
Judith Atkinson, Washington, D. C., white rabbit.
Vernon Bailey, Washington, D. C., 5 antelope squirrels, 2 eastern chipmunks, mountain wood rat.
Robert Ball, Washington, D. C., Pekin duck.
Herbert Barber, National Museum, Washington, D. C., mink.
Dr. T. Barbour, Museum of Comparative Zoology, Cambridge, Mass., 3 Florida king snakes, 2 chicken snakes, garter snake, glass snake or legless lizard, horn snake.
Mrs. Bemar, Bradbury, Md., 5 opossums.
J. B. Berry, Washington, D. C., red fox.
Howard Blanchard, Arlington, Va., 5 horned lizards.
Mrs. Blumenberg, Washington, D. C., common pigeon.
Warren Bowman, Washington, D. C., milk snake.
Miss Wilma Bradford, Washington, D. C., 2 cottontail rabbits.
David S. Brown, Washington, D. C., Florida diamond-backed rattlesnake.
Mrs. R. Brown, Washington, D. C., robin.
J. Brylawski, Washington, D. C., great horned owl.
Mrs. J. S. Burdette, Kensington, Md., double yellow-head parrot.
W. W. Campbell, Riverdale, Md., barred owl.
Patricia Chambers, Washington, D. C., white rabbit.
Mrs. Cipriano, Washington, D. C., angora rabbit.
Charles Clark, District Training School, Laurel, Md., 2 red-tailed hawks.
Mrs. M. O. Clarke, Chevy Chase, Md., red-tailed hawk.
Mrs. H. Clements, Washington, D. C., white-eyed parrot.
Elias Cohen, Washington, D. C. (through J. N. Hamlet), copperhead snake.
H. James Cole, Bethesda, Md., 4 green tree frogs, hog-nosed snake, 2 garter snakes, 6 common tree frogs.
Martin S. Cooper, Arlington, Va., ring-necked pheasant.
Mrs. B. J. Costello, Arlington, Va., 2 alligators.
R. E. Crouch, Washington, D. C., oppossum.
Mrs. E. C. Davis, Washington, D. C., 20 guinea pigs, rabbit.
Harry Day, Hyattsville, Md., king snake, 11 painted turtles, 9 spotted turtles, snapping turtle, 2 musk turtles.
W. M. DeNeane, Washington, D. C., common iguana.
Benjamin C. Dooley, National Zoological Park, red-breasted merganser.

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Charles East, National Museum, Washington, D. C., pilot snake, fox snake.
Robert Ellis, Washington, D. C., king rail.
Mrs. M. J. Fadgen, Baltimore, Md., troupial.
Dr. Ferguson, Washington, D. C., eastern cardinal.
Albert A. Fields, Washington, D. C., rough-scaled green snake.
Firestone Plantation, Harbel, Liberia, pigmy hippopotamus, western chimpanzee, leopard, 2 rhinoceros vipers, green mamba.
Firestone Tire & Rubber Co., Akron, Ohio, East African porcupine, crowned hawk-eagle.
Fish and Wildlife Service, Department of the Interior, Beltsville, Md., 12 Canada geese.
Fish and Wildlife Service, Department of the Interior, Washington, D. C., 8 black ducks.
Fish and Wildlife Service, Mattamuskeet Refuge, New Holland, N. C., pintail duck.
Fish and Wildlife Service, Sacramento National Wild Life Refuge, Sacramento, Calif., 10 cackling geese.
Fish and Wildlife Service, Seney Northwest Refuge, Germfask, Mich., 2 blue-winged teal.
Fish and Wildlife Service, Department of the Interior, Wichita Mountains, Wildlife Refuge, Cache, Okla., American elk.
Fish and Wildlife Service, through H. A. Bailey, Pungo, Va., 3 whistling swans.
Fish and Wildlife Service, through John N. Hamlet, Washington, D. C., Florida diamond-back rattlesnake, pigmy rattlesnake, chicken snake, pine snake, coachwhip snake, 2 pilot snakes, 2 eastern porcupines.
Fish and Wildlife Service, through John M. Hopkins, Waycross, Ga., bald eagle.
Fish and Wildlife Service through William Hopkins, McBee, S. C., for Carolina Sandhills Refuge, wood duck.
Fish and Wildlife Service, through George Mushbach, National Bison Range, Moise, Mont., bald eagle.
Fish and Wildlife Service, through Sam A. Walker, Manteo, S. C., 2 blue-winged teal, 6 American coots.
Ralph Fisher, Hyattsville, Md., opossum.
W. M. Fitch, Washington, D. C., alligator.
Wiley Ford, Washington, D. C., 3 guinea pigs.
L. V. Friedlei, Washington, D. C., Pekin duck.
Mrs. J. Friedman, Washington, D .C., screech owl.
William Gee, Washington, D. C., barred owl.
J. Gott, Washington, D. C., least bittern.
Norman Gramam, Suitland, Md., great blue heron.
W. B. Greenwood, Washington, D. C., 2 western rattlesnakes.
Martha Hall, Glen Dale Sanatorium, Glen Dale, Md., Pekin duck.
John N. Hamlet, Washington, D. C., tayra.
Major C. V. Haynes, Langley Field, Va., ocelot.
Helen H. Haynes, Washington, D. C., Pekin thrush.
A. M. Hazel, Washington, D. C., barrel owl.
Dr. A. Henry, Washington, D. C., weasel.
Mrs. F. W. Hill, Washington, D. C., blue jay.
G. A. Holland, Texas, 4 Texas rattlesnakes.
Miss Hopkins, Washington, D. C., mourning dove.
Miss G. E. Hudson, Washington, D. C., painted turtle.
N. Hynson, Washington, D. C., Pekin duck.
Mr. Jacobsen, Arlington, Va., 3 peafowl.

Mr. and Mrs. C. M. James, Landover, Md., horned owl, 2 valley quail, bobwhite.
G. H. Jelinek, Washington, D. C., Pekin duck.
Mr. and Mrs. Joseph M. Joel, Washington, D. C., ferret.
A. L. Johns, Washington, D. C., painted turtle.
Sgt. D. Jones, Police Department, Rockville, Md., black widow spider.
John Paul Jones, Washington, D. C., opossum.
Dr. Howard A. Kelly, Baltimore, Md., 2 marmosets.
William Kennedy, Washington, D. C., sparrow hawk.
C. S. Kimball, Washington, D. C., Virginia rail.
Mrs. H. Kingsland, "Blackstable," Aiken, S. C., 2 barred owls.
Mrs. Krast, Washington, D. C., alligator.
Mrs. H. W. Lambert, Washington, D. C., 2 painted turtles.
Brady D. Large, Washington, D. C., ring-necked pheasant.
George Leonard, Washington, D. C., alligator.
O. M. Locke, New Braunfels, Tex., 52 horned lizards.
Mr. Lovell, Washington, D. C., large brown bat.
Mrs. A. N. Lukacs, Washington, D. C., skunk.
Ernest Lupton, Washington, D. C., black-crowned night heron.
Mrs. J. A. Lyon, Washington, D. C., 2 Arkansas goldfinch, painted bunting.
Mrs. J. A. Mandley, Washington, D. C., white-throated capuchin.
Mrs. L. O. Manley, Chevy Chase, Md., ferret.
J. P. Marshall, Alexandria, Va., great blue heron.
Mrs. J. J. Marvel, Takoma Park, Md., Cuban parrot.
Edward Matteossion, Bethesda, Md., weasel.
Sgt. J. McAuliffe, Bethesda, Md., barred owl.
B. McClellen, Washington, D. C., barred owl.
Henry J. McDermott, Takoma Park, Md., 2 canaries.
R. A. McGee, Washington, D. C., opossum.
E. A. McIlhenny, Avery Island, La., 15 pintails, 3 green-winged teal, 4 canvasback ducks, 7 lesser scaup, 5 coots, 24 blue-winged teal, 3 Florida gallinule, 6 blue geese, 2 lesser snow geese, 3 hybrid ducks (greenhead and black mallard), ring-necked duck.
Evan McLaughlin, Washington, D. C., ring-necked snake.
Dr. H. R. Mills, Tampa, Fla., bald eagle.
Vernon Mills, Fallon, Nev., 7 soft-haired ground squirrels.
Mrs. R. T. Minahan, Baltimore, Md., common marmoset.
Miss V. Moore, Washington, D. C., great white heron.
G. Myers, Stanford University, Palo Alto, Calif., 33 California newts.
National Institute of Health, through Dr. J. Oliphant, 2 golden hamsters.
J. A. Nettle, Washington, D. C., screech owl.
New York Zoological Park, 3 tahr goats.
Newbold Noyes, Evening Star, Washington, D. C., 2 black bears.
James O'Hagen, Washington, D. C., woodchuck or ground hog.
Mrs. H. A. Ourand, Takoma Park, Md., red-shouldered hawk.
Logan Owens, Jr., Washington, D. C., coot.
Miss Nancy Pelty, Washington, D. C., Pekin duck.
Dr. Elmo Peters, Washington, D. C., alligator.
Capt. S. Picking, Coco Sola, Canal Zone, Panama, 2 Galapagos tortoises.
John A. Plugge, Chevy Chase, Md., snapping turtle.
Mrs. Virginia Poore, Mount Rainier, Md., white-throated capuchin.
Mrs. Edward Portner, Washington, D. C., 4 skunks.
Mrs. Pratt, Washington, D. C., turtle.
Miss G. V. Rainey, Takoma Park, Md., alligator.

Mildred Reed, Washington, D. C., water snake.
Mrs. James Reeks, Washington, D. C., 4 snapping turtles.
Mrs. Rehbein, Washington, D. C., weasel.
N. M. Rhodes, Dispensary Bldg., U. S. Naval Academy, Annapolis, Md., ocelot.
Dr. Waldo Schmitt, National Museum, Washington, D. C., 2 James Island snakes, South Seymour Island snake.
Mrs. Scott, Washington, D. C., alligator.
Mrs. Lizzie Shelby, Washington, D. C., 4 pine snakes.
Mrs. Sherry, Washington, D. C., 2 common rabbits.
Robert Shore, Washington, D. C., red fox.
Mr. and Mrs. Phillip Shorts, Lander, Wyo., Philippine monkey.
Robert Shosteck, Washington, D. C., fence lizard, snapping turtle.
C. L. Sibley, Wallingford, Conn., 3 bantam chickens.
Orville S. Simpson, Washington, D. C., tovi paroquet.
B. Sisson, Washington, D. C., 2 Pekin ducks.
Mrs. R. Sizemore, Mount Rainier, Md., 2 Muscovy ducks.
Donald Skinker and William Wohlfarth, Washington, D. C., 3 garter snakes.
Joy Eloise Smith, Washington, D. C., 2 Pekin ducks.
R. Smith, Washington, D. C., Pekin duck.
Smithsonian-Firestone Expedition to Liberia—see field work.
Soldiers' Home, Washington, D. C., red-shouldered hawk.
W. H. Sterling, West Falls Church, Va., black widow spider.
Louis Stone, Washington, D. C., mole snake.
Rex Sullivan, Hudson, N. C., smooth green snake.
Miss L. C. Tait, Washington, D. C., zebra finch.
Clifton Taylor, Hyattsville, Md., snapping turtle, king or chain snake.
Robert Thulman, Chevy Chase, Md., white king pigeon.
Patricia and Terry Townsend, Washington, D. C., Pekin duck.
Miss J. Tendrik, Washington, D. C., Pekin duck.
Tropical Fruit Shop, Washington, D. C., opossum.
Dr. W. G. Trow, Warrenton, Va., barred owl.
U. S. Antarctic Service, Washington, D. C., 3 emperor penguins, 4 Gentoo penguins, 2 kelp gulls, giant fulmar.
J. W. Urban, Arlington, Va., society finch, zebra finch.
Albert Valeer, Washington, D. C., 3 common rabbits.
Guillermo Valenzuela, Matagalpa, Nicaragua, Nicaraguan titi monkey.
Ernest P. Walker, National Zoological Park, Washington, D. C., 5 ornate turtles, bull snake.
Washington National Airport, Dispensary Building, ring-billed gull.
Mrs. Way, Washington, D. C., 3 alligators.
Mrs. Lena White, Harpers Ferry, W. Va., double yellow-head parrot.
Karl Weissman, Kew Gardens, Long Island, N. Y., brown capuchin.
Mrs. Martin Welch, Seat Pleasant, Md., opossum.
Jess Williams, Washington, D. C., barred owl.
Lanier Williams, Washington, D. C., water snake, milk snake.
Shirley Ann Williams, Washington, D. C., sparrow hawk.
Miss Katherine A. Zehrfeld, Washington, D. C., alligator.

BIRTHS

There were 70 mammals born, 49 birds hatched, and 14 reptiles born or hatched during the year.

MAMMALS

Scientific name	*Common name*	*Number*
Ammotragus lervia	Aoudad	3
Aotus trivirgatus	Douroucouli or owl monkey	2
Axis axis	Axis deer	2
Bison bison	American bison	3
Bos indicus	Zebu	1
Canis dingo	Dingo	3
Canis lupus nubilus	Plains wolf	4
Canis rufus	Texas red wolf	9
Cervus elaphus	European red deer	1
Choeropsis liberiensis	Pigmy hippopotamus	1
Cricetus cricetus subsp	Golden hamster	9
Dama dama	Fallow deer	4
Dendrolagus inustus	Tree kangaroo	1
Dolichotis magellanica	Patagonian cavy	3
Felis onca	Jaguar	2
Lama pacos	Alpaca	1
Leontocebus rosalia	Lion-headed or golden marmoset	2
Macaca mulatta	Rhesus monkey	1
Macaca nemestrina	Pig-tailed macaque	1
Myocastor coypu	Coypu or nutria	3
Oncifelis geoffroyi	Geoffroy's cat	1
Petaurus breviceps	Lesser flying phalanger	6
Procyon lotor	Black raccoon	5
Vulpes fulva	Red fox	2

BIRDS

Branta canadensis	Canada goose	16
Guara alba×*G. rubra*	Hybrid ibis	1
Limnocorax flavirostra	African black rail	4
Nycticorax nycticorax naevius	Black-crowned night heron	16
Pavo cristatus	Blue peafowl	12

REPTILES

Crotalus adamanteus	Florida diamond-backed rattlesnake	14

EXCHANGES

There were not a great number of specimens received during the year through the medium of exchange. Ennio Arrigutti, Buenos Aires, Argentina, continued his shipments of desirable South American animals. The New York Zoological Park sent a purple-crested plantain eater. A pair of green Japanese pheasants was received from the Miami Rare Bird Farm, Miami, Fla. Several shipments of reptiles have again been received from C. W. Kern, Tujunga, Calif.

PURCHASES

The more important specimens acquired by purchase were a harpy eagle and a pair of South American bush dogs, three naked-throated

bell birds, a pair of raccoon dogs, a pair of Chinese badgers and a pair of Peruvian viscachas. Also purchased during the year were a pair each of vicunas and llamas. This completed our exhibit of all the American representatives of the camel family.

REMOVALS

DEATHS

A most serious loss during the year was the number of birds, mostly parrots, which died as the result of an epidemic of psittacosis in the bird house. A number of birds suspected of having the disease were put to death. The entire building was closed, on advice of the Department of Health, District of Columbia, for about 3 months. The parrot room is still closed to the public. It is believed that the situation is now well on the way to being cleared. Other losses included several chevrotain, and an East African leopard, the last of the lot received in 1926 from the Smithsonian-Chrysler expedition. A brown hyena which had been in the collection since 1928 died during the year. As in the past, all specimens of scientific value that died during the year were sent to the National Museum.

SPECIES NEW TO THE HISTORY OF THE COLLECTION

MAMMALS

Scientific name	*Common name*
Cephalophus niger	Black duiker.
Cephalophus nigrifrons	Black-fronted duiker.
Euxerus erythropus lacustris	African ground squirrel.
Galerella melanura	Dwarf civet.
Genetta poensis	Dark genet.
Lagidium viscaccia	Peruvian viscacha.
Meles meles leptorhynchus	Chinese badger.
Nandinia binotata	African palm civet.

BIRDS

Buteo poecilochrous	Red-backed buzzard.
Gallirex porphyreolophus	Purple-crested plantain eater.
Gypohierax angolensis	Fish-eating vulture.
Larus dominicanus	Kelp gull.
Macronectes giganteus	Giant fulmar.
Pygoscelis papua	Gentoo penguin.

REPTILES

Kinixys erosa	West African back-hinged tortoise.

Statement of accessions

How acquired	Mammals	Birds	Reptiles	Amphibians	Fishes	Arachnids	Total
Presented	80	207	165	10	10	3	475
Born or hatched	70	49	14				133
Received in exchange	16	40	39	34			129
Purchased	13	57	16	2	50		138
On deposit	18	34					52
Received from Smithsonian-Firestone Expedition to Liberia	41	31	23	15			110
Received from Antarctic Expedition		10					10
Totals	238	428	257	61	60	3	1,047

Summary

Animals on hand July 1, 1940	2,550
Accessions during the year	1,047
Total animals in collection during year	3,597
Removal from collection by death, exchange, and return of animals on deposit	1,217
In collection June 30, 1941	2,380

Status of collection

Class	Species	Individuals	Class	Species	Individuals
Mammals	221	701	Insects	1	26
Birds	327	980	Mollusks	1	5
Reptiles	124	439	Crustaceans	1	3
Amphibians	23	79			
Fishes	30	144	Total	730	2 380
Arachnids	2	3			

A list of the animals in the collection follows:

ANIMALS IN THE NATIONAL ZOOLOGICAL PARK, JUNE 30, 1941

MAMMALS

MARSUPIALIA

Didelphidae:		
Didelphis virginiana	Opossum	4
Dasyuridae:		
Sarcophilus ursinus	Tasmanian devil	1
Phalangeridae:		
Petaurus breviceps	Lesser flying phalanger	9
Trichosurus vulpecula	Vulpine opossum	1
Macropodidae:		
Dendrolagus inustus	Tree kangaroo	3
Dendrolagus inustus finschi	Finsches tree kangaroo	3
Dendrolagus ursinus × *D. inustus*	Hybrid tree kangaroo	1
Phascolomyidae:		
Vombatula ursina	Flinders Island wombat	2

CHIROPTERA

Vespertilionidae:		
Eptesicus fuscus	Large brown bat	1

CARNIVORA

Felidae:		
Acinonyx jubatus	Cheeta	2
Felis chaus	Jungle cat	1
Felis concolor puma	Patagonian puma	1
Felis leo	Lion	5
Felis onca	Jaguar	4
	Black jaguar	2
Felis pardalis	Ocelot	3
Felis pardus	Indian leopard	5
	Black Indian leopard	2
Felis tigrina	Margay	1
Felis tigris	Bengal tiger	2
Felis tigris longipilis	Siberian tiger	1
Felis tigris sondaicus	Sumatran tiger	4
Lynx baileyi	Bailey's lynx	1
Lynx rufus	Bay lynx	3
Lynx uinta	Bobcat	1
Neofelis nebulosa	Clouded leopard	1
Oncifelis geoffroyi	Geoffroy's cat	4
Profelis temmincki	Golden cat	3
Viverridae:		
Arctictis binturong	Binturong	1
Civettictis civetta	Civet	2
Galerella melanura	Dwarf civet	1
Moschothera megaspila	Burmese civet	1
Nandinia binotata	African palm civet	1
Paradoxurus hermaphrodytus	Small-toothed palm civet	1
Hyaenidae:		
Crocuta crocuta germinans	East African spotted hyena	1
Canidae:		
Canis latrans	Coyote	7
Canis latrans × *domestica*	Coyote and dog hybrid	2
Canis lupus lycaon	Timber wolf	2
Canis lupus nubilus	Wolf	4
Canis rufus	Texas red wolf	7
Chrysocyon jubata	Maned wolf	1
Cuon javanicus sumatrensis	Sumatran wild dog	1
Dusicyon sp	South American fox	1
Dusicyon sp	South American fox	5
Urocyon cinereoargenteus	Gray fox	6
Vulpes fulva	Red fox	12
Procyonidae:		
Nasua narica	Coatimundi	4
Potos flavus	Kinkajou	5
Procyon lotor	Raccoon	7
	Raccoon (albino)	1
	Black raccoon	8
Bassariscidae:		
Bassariscus astutus	Ring-tail or cacomistle	3

Mustelidae:		
Arctonyx collaris	Hog badger	1
Atilax pluto	Water civet	1
Charronia flavigula henricii	Asiatic marten	1
Galictis barbara barbara	White tayra	2
Galictis sp	Brown tayra	1
Grison allamandi	Huron	1
Grisonella huronax	Grison	2
Gulo luscus	Wolverine	1
Lutra canadensis vaga	Florida otter	1
Meles meles	European badger	2
Mellivora capensis	Ratel	1
Mephitis nigra	Skunk	16
Micraonyx leptonyx	Small-clawed otter	1
Mustela eversmanni	Ferret	1
Mustela noveboracensis	Weasel	2
Mustela vison vison	Mink	1
Ursidae:		
Euarctos americanus	American black bear	4
Euarctos emmonsii	Glacier bear	1
Helarctos malayanus	Malay or sun bear	1
Thalarctos maritimus	Polar bear	2
Thalarctos maritimus×*Ursus middendorffi*	Hybrid bear	5
Ursus arctos	European brown bear	1
Ursus gyas	Alaska Peninsula bear	4
Ursus middendorffi	Kodiak brown bear	3
Ursus sitkensis	Sitka brown bear	3
Ursus thibetanus	Himalayan bear	3

PINNIPEDIA

Otariidae:		
Zalophus californianus	California sea lion	1
Phocidae:		
Phoca richardii	Pacific harbor seal	3

PRIMATES

Lemuridae:		
Nycticebus coucang	Slow loris	4
Perodicticus potto	Potto	1
Callitrichidae:		
Callithrix jacchus	Common marmoset	1
Leontocebus rosalia	Lion-headed or golden marmoset	2
Mico argentata	Black-tailed marmoset	1
Oedipomidas oedipus	Pinche tamarin	1
Saimiridae:		
Saimiri sp	Nicaraguan titi monkey	2
Cebidae:		
Aotus trivirgatus	Douroucouli or owl monkey	8
Cebus apella	Brown capuchin	7
Cebus capucinus	White-throated capuchin	1
Cebus fatuellus	Weeping capuchin	3
Cebus sp	Gray capuchin	1
Pithecia monacha	Saki monkey	1

Cercopithecidae:		
Cercocebus fuliginosus	Sooty mangabey	19
Cercopithecus aethiops aethiops	Grivet monkey	1
Cercopithecus aethiops sabaeus	Green guenon	7
Cercopithecus diana	Diana monkey	1
Cercopithecus neglectus	De Brazza's guenon	1
Cercopithecus petaurista	Lesser white-nosed guenon	1
Cercopithecus roloway	Roloway monkey	1
Erythrocebus patas	Patas monkey	2
Macaca fuscata	Japanese monkey	2
Macaca lasiotis	Chinese macaque	2
Macaca mordax	Javan monkey	9
Macaca mulatta	Rhesus monkey	4
Macaca nemestrina	Pig-tailed macaque	6
Macaca silenus	Wanderoo monkey	1
Macaca sinica	Toque or bonnet monkey	3
Magus maurus	Moor monkey	5
Mandrillus leucophaeus	Drill	1
Mandrillus sphinx	Mandrill	3
Papio comatus	Chacma	1
Papio papio	West African baboon	1
Papio sp	West African baboon	1
Presbytis senex nestor	Western purple-faced monkey	2
Hylobatidae:		
Hylobates agilis	Sumatran gibbon	1
Hylobates lar pileatus	Black-capped gibbon	1
Symphalangus syndactylus	Siamang gibbon	1
Pongidae:		
Pan satyrus	Chimpanzee	4
Pan satyrus verus	Western chimpanzee	1
Pongo abelii	Sumatran orangutan	2
Pongo pygmaeus	Bornean orangutan	1

RODENTIA

Sciuridae:		
Ammospermophilus leucurus	Antelope squirrel	4
Citellus mollis	Soft-haired ground squirrel	4
Cynomys ludovicianus	Prairie dog	16
Glaucomys volans	Flying squirrel	1
Marmota monax	Woodchuck or ground hog	3
Sciurus finlaysoni	Lesser white squirrel	2
Sciurus niger	Southern fox squirrel	3
Tamias striatus	Eastern chipmunk	3
Tamiasciurus hudsonicus	Red squirrel	1
Heteromyidae:		
Dipodomys deserti	Desert kangaroo rat	1
Dipodomys merriami	Merriam kangaroo rat	1
Jaculidae:		
Jaculus jaculus	Egyptian jerboa	1
Castoridae:		
Castor canadensis	Beaver	1

Cricetidae:		
Cricetus cricetus subsp	Golden hamsters	23
Cricetomys gambianus	Gambia pouched rat	6
Neotoma floridana attwateri	Round-tailed wood rat	1
Ondatra zibethica	Black muskrat	1
Peromyscus californicus	Long-tailed mouse	1
Peromyscus leucopus	White-footed mouse	6
Peromyscus leucopus noveboracensis	Northern white-footed mouse	2
Peromyscus maniculatus	White-footed mouse	2
Peromyscus maniculatus osgoodi	Black-eared deer mouse	1
Peromyscus polionotus polionotus	Old-field mouse	1
Muridae:		
Rattus norvegicus (albino)	White rat	2
Hystricidae:		
Acanthion brachyurum	Malay porcupine	5
Atherurus africana	West African brush-tailed porcupine	3
Hystrix galeata	East African porcupine	2
Thecurus sumatrae	Brush-tailed porcupine	1
Erethizontidae:		
Coendou prehensilis	Prehensile-tailed porcupine	2
Erithizon dorsatum	Eastern porcupine	1
Erithizon epixanthum	Western porcupine	1
Myocastoridae:		
Myocastor coypu	Nutria	19
Capromyidae:		
Capromys pilorides	Hutia	1
Cuniculidae:		
Cuniculus paca virgatus	Central American paca	1
Dasyproctidae:		
Dasyprocta croconota prymnolopha	Agouti	2
Chinchillidae:		
Lagidium viscaccia	Peruvian viscacha	2
Caviidae:		
Cavia porcellus	Domestic guinea pig	25
Cavia porcellus	Domestic guinea pig (angora breed)	3
Dolichotis magellanica	Patagonian cavy	5
Pediolagus salinicola	Dwarf cavy	1

LAGOMORPHA

Leporidae:		
Oryctolagus cuniculus	Domestic rabbit	7

ARTIODACTYLA

Bovidae:		
Ammotragus lervia	Aoudad	19
Anoa depressicornis	Anoa	2
Bibos gaurus	Gaur	3
Bison bison	American bison	19
	Albino bison	1
Bos indicus	Zebu	4
Bubalus bubalis	Indian buffalo	1

Bovidae—Continued.		
Cephalophus niger	Duiker	2
Cephalophus nigrifrons	Black-fronted duiker	3
Connochaetes gnu	White-tailed gnu	2
Hemitragus jemlahicus	Tahr	4
Oryx beisa annectens	Ibean beisa oryx	2
Ovis europaeus	Mouflon	2
Poephagus grunniens	Yak	6
Pseudois nahura	Bharal or blue sheep	5
Synceros caffer	African buffalo	2
Taurotragus oryx	Eland	3
Cervidae:		
Axis axis	Axis deer	9
Cervus canadensis	Wapiti	3
Cervus duvaucelii	Barasingha deer	2
Cervus elaphus	European red deer	14
Dama dama	Brown fallow deer	11
	White fallow deer	14
Muntiacus muntjak	Rib-faced or barking deer	1
Muntiacus sinensis	Chinese rib-faced deer	1
Odocoileus costaricensis	Costa Rican deer	1
Odocoileus virginianus	Virginia deer	3
Sika nippon	Japanese deer	2
Tragulidae:		
Tragulus javanicus	Javan mouse deer	1
Giraffidae:		
Giraffa camelopardalis	Nubian giraffe	4
Giraffa reticulata	Reticulated giraffe	2
Camelidae:		
Camelus bactrianus	Bactrian camel	3
Lama glama	Llama	2
Lama huanacus	Guanaco	2
Lama pacos	Alpaca	2
Vicugna vicugna	Vicuna	2
Tayassuidae:		
Pecari angulatus	Collared peccary	3
Tayassu pecari	White-lipped peccary	1
Suidae:		
Babirussa celfurus	Babirussa	3
Phacochoerus aethiopicus massaicus	East African wart hog	1
Sus scrofa	European wild boar	1
Hippopotamidae:		
Choeropsis liberiensis	Pigmy hippopotamus	5
Hippopotamus amphibius	Hippopotamus	2

PERISSODACTYLA

Equidae:		
Equus grevyi	Grevy's zebra	1
Equus grevyi-asinus	Zebra-ass hybrid	1
Equus grevyi-caballus	Zebra-horse hybrid	1
Equus kiang	Asiatic wild ass or kiang	2
Equus przewalskii	Mongolian wild horse	3
Equus quagga chapmani	Chapman's zebra	7
Equus zebra	Mountain zebra	1

Tapiridae:		
Acrocodia indica	Asiatic tapir	2
Tapirella bairdii	Central American tapir	1
Tapirus terrestris	South American tapir	2
Rhinocerotidae:		
Diceros bicornis	Black rhinoceros	1
Rhinoceros unicornis	Great Indian one-horned rhinoceros	1

PROBOSCIDEA

Elephantidae:		
Elephas sumatranus	Sumatran elephant	1
Loxodonta africana oxyotis	African elephant	1

EDENTATA

Choloepodidae:		
Choloepus didactylus	Two-toed sloth	1
Dasypodidae:		
Chaetophractus villosus	Hairy armadillo	1
Dasypus novemcinctus	Nine-banded armadillo	1

BIRDS

STRUTHIONIFORMES

Struthionidae:		
Struthio camelus	South African ostrich	1

RHEIFORMES

Rheidae:		
Rhea americana	Common rhea or nandu	3
	White rhea	3

CASUARIIFORMES

Casuariidae:		
Casuarius bennetti	Bennett's cassowary	1
Casuarius sp	——— cassowary	1
Casuarius unappendiculatus	Single-wattled cassowary	3
Dromiceiidae:		
Dromiceius novaehollandiae	Common emu	2

SPHENISCIFORMES

Spheniscidae:		
Aptenodytes forsteri	Emperor penguin	3
Pygoscelis papua	Gentoo penguin	3
Spheniscus demersus	Jackass penguin	4

TINAMIFORMES

Tinamidae:		
Calopezus elegans	Crested tinamou	2
Nothura maculosa	Spotted tinamou	1

PELECANIFORMES

Pelecanidae:		
Pelecanus californicus	California brown pelican	2
Pelecanus conspicillatus	Australian pelican	5
Pelecanus erythrorhynchos	American white pelican	5

Pelecanidae—Continued.		
Pelecanus erythrorhynchos×P. occidentalis	American white and brown pelican (hybrid)	1
Pelecanus occidentalis	Brown pelican	2
Pelecanus onocrotalus	European pelican	2
Pelecanus roseus	Rose-colored pelican	2
Sulidae:		
Morus bassanus	Gannet	1
Phalacrocracidae:		
Phalacrocorax auritus albociliatus	Farallon cormorant	1
Phalacrocorax auritus floridanus	Florida cormorant	1
Anhingidae:		
Anhinga anhinga	Anhinga	1
Fregatidae:		
Fregata ariel	Lesser frigate bird	2
CICONIIFORMES		
Ardeidae:		
Ardea herodias	Great blue heron	1
Ardea occidentalis	Great white heron	1
Notophoyx novaehollandiae	White-faced heron	1
Nycticorax nycticorax naevius	Black-crowned night heron	20
Cochleariidae:		
Cochlearius cochlearius	Boatbill heron	3
Ciconiidae:		
Dissoura episcopus	Woolly-necked stork	1
Ephippiorhynchus senegalensis	Saddle-billed stork	1
Ibis cinereus	Malay stork	2
Leptoptilus crumeniferus	Marabou	1
Leptoptilus dubius	Indian adjutant	1
Leptoptilus javanicus	Lesser adjutant	2
Mycteria americana	Wood ibis	1
Threskiornithidae:		
Ajaia ajaja	Roseate spoonbill	1
Guara alba	White ibis	2
Guara alba×G. rubra	Hybrid ibis (scarlet and white)	1
Guara rubra	Scarlet ibis	2
Threskiornis aethiopica	Sacred ibis	2
Threskiornis melanocephala	Black-headed ibis	4
Threskiornis spinicollis	Straw-necked ibis	2
Phoenicopteridae:		
Phoenicopterus chilensis	Chilean flamingo	2
PROCELLARIIFORMES		
Procellaridae:		
Macronectes giganteus	Giant fulmar	1
ANSERIFORMES		
Anhimidae:		
Chauna cristata	Crested screamer	9
Anatidae:		
Aix sponsa	Wood duck	9

Anatidae—Continued.

Alopochen aegyptiacus	Egyptian goose	1
Anas brasiliensis	Brazilian teal	2
Anas domestica	Pekin duck	27
Anas platyrhynchos	Mallard duck	28
Anas rubripes	Black or dusty mallard	1
Anser albifrons	American white-fronted goose	3
Anser cinereus domestica	Toulouse goose	1
Anserinas semipalmata	Australian pied goose	2
Branta bernicla	Brant	1
Branta canadensis	Canada goose	20
Branta canadensis minima	Cackling goose	10
Branta canadensis occidentalis	White-cheeked goose	15
Cairina moschata	Muscovy duck	8
Casarca variegata	Paradise duck	1
Cereopsis novaehollandiae	Cereopsis or Cape Barren goose	1
Chen atlantica	Snow goose	7
Chen caerulescens	Blue goose	8
Chenopis atrata	Black swan	4
Chloephaga leucoptera	Magellan goose	1
Chloephaga poliocephala	Ashy-headed upland goose	2
Coscoroba coscoroba	Coscoroba	2
Cygnopsis cygnoides	Chinese goose	3
Cygnus columbianus	Whistling swan	5
Cygnus melancoriphus	Black-necked swan	2
Cygnus olor	Mute swan	2
Dafila acuta	Pintail	8
Dafila spinicauda	Chilean pintail	1
Dendrocygna arborea	Black-billed tree duck	3
Dendrocygna autumnalis	Black-bellied tree duck	2
Dendrocygna viduata	White-faced tree duck	4
Mareca americana	Baldpate	1
Marila affinis	Lesser scaup	2
Marila collaris	Ring-necked duck	1
Nettion carolinense	Green-winged teal	1
Nyroca sp	Hybrid duck	1
Nyroca valisineria	Canvasback duck	2
Plectropterus gambensis	Spur-winged goose	2
Querquedula discors	Blue-winged teal	13

FALCONIFORMES

Cathartidae:

Aegypius monachus	Cinereous vulture	1
Cathartes aura	Turkey vulture	3
Cathartes aura×*Coragyps atratus*	Black vulture and turkey vulture hybrid	1
Coragyps atratus	Black vulture	1
Gymnogyps californianus	California condor	2
Gypohierax angolensis	Fish-eating vulture	1
Gyps rueppelli	Ruppell's vulture	1
Kaupifalco monogrammicus	Northern lizard-buzzard	1
Sarcoramphus papa	King vulture	1
Torgos tracheliotus	African eared vulture	1
Vultur gryphus	South American condor	3

Sagittariidae:		
Sagittarius serpentarius	Secretary bird	2
Accipitridae:		
Accipiter tachiro macroscelides	West African goshawk	1
Buteo borealis	Red-tailed hawk	8
Buteo lineatus	Red-shouldered hawk	2
Buteo melanoleucus	South American buzzard eagle	2
Buteo poecilochrous	Red-backed buzzard	3
Buteo swainsoni	Swainson's hawk	1
Haliaeetus leucocephalus	Bald eagle	12
Haliastur indus	Brahminy kite	3
Harpia harpya	Harpy eagle	2
Hypomorphnus urubitinga	Brazilian eagle	1
Milvago chimango	Chimango	3
Milvus migrans parasitus	Yellow-billed kite	3
Pandion haliaetus carolinensis	Osprey or fish hawk	1
Parabuteo unicinctus	One-banded hawk	1
Stephanoaetus coronatus	Crowned hawk-eagle	3
Uroaetus audax	Wedge-tailed eagle	1
Falconidae:		
Cerchneis sparverius	Sparrow hawk	1
Cerchneis sparverius cinnamominus	Chilean sparrow hawk	2
Daptrius americanus	Carancho	3
Polyborus cheriway	Audubon's caracara	2
Polyborus plancus	South American caracara	1

GALLIFORMES

Cracidae:		
Crax fasciolata	Crested curassow	3
Crax rubra	Panama curassow	1
Crax sclateri	Sclater's curassow	2
Mitu mitu	Razor-billed curassow	3
Penelope sp.	Guan	2
Phasianidae:		
Alectoris graeca	Chukar partridge	1
Argusianus argus	Argus pheasant	2
Chrysolophus amherstiae	Lady Amherst's pheasant	1
Chrysolophus pictus	Golden pheasant	7
Colinus virginianus	Bobwhite	1
Coturnix coturnix	Migratory quail	5
Excalfactoria chinensis	Blue-breasted button quail	4
Gallus gallus	Jungle fowl	2
Gallus lafayetti	Ceylonese jungle fowl	1
Gallus sp.	Bantam fowl	2
Gallus sp.	Araucanian fowl	4
Gallus sp. × *Numida galeata*	Chicken and guinea fowl hybrid	2
Gennaeus lineatus	Lineated pheasant	1
Gennaeus nycthemerus	Silver pheasant	2
Hierophasis swinhoii	Swinhoe's pheasant	1
Lophophorus impeyanus	Himalayan impeyan pheasant	1
Lophortyx californica vallicola	Valley quail	2
Lophura rubra	Malayan fire-back pheasant	1
Pavo cristatus	Peafowl	13

Phasianidae—Continued.		
Pavo muticus	Green peafowl	1
Phasianus torquatus	Ring-necked pheasant	1
	White ring-necked pheasant	2
Phasianus torquatus formosanus	Formosan ring-necked pheasant	1
Phasianus torquatus (var.)	Melanistic mutant ring-necked pheasant	3
Phasianus versicolor	Green Japanese pheasant	4
Polyplectron napoleonis	Palawan peacock pheasant	1
Syrmaticus reevesi	Reeves' pheasant	1
Numididae:		
Acryllium vulturinum	Vulturine guinea fowl	1
Numida sp	Guinea fowl	4
GRUIFORMES		
Gruidae:		
Anthropoides paradisea	Paradise crane	2
Anthropoides virgo	Demoiselle crane	7
Balearica pavonina	West African crowned crane	3
Balearica regulorum gibbericeps	East African crowned crane	1
Fulica americana	American coot	10
Grus canadensis canadensis	Little brown crane	1
Grus leucauchen	White-naped crane	1
Grus leucogeranus	Siberian crane	2
Rallidae:		
Gallinula chloropus cachinnans	Florida gallinule	4
Gallinula chloropus orientalis	Sumatran gallinule	2
Limnocorax flavirostra	African black rail	10
Porphyrio poliocephalus	Gray-headed porphyrio	2
Eurypygidae:		
Eurypyga helias	Sun bittern	1
Cariamidae:		
Cariama cristata	Cariama or seriama	2
CHARADRIIFORMES		
Haematopodidae:		
Haematopus ostralegus	European oyster catcher	2
Charadriidae:		
Belonopterus chilensis	Chilean lapwing	2
Scolopacidae:		
Philomachus pugnax	Ruff	1
Laridae:		
Larus argentatus	Herring gull	1
Larus delawarensis	Ring-billed gull	1
Larus dominicanus	Kelp gull	2
Larus glaucescens	Glaucous-winged gull	1
Larus novaehollandiae	Silver gull	16
COLUMBIFORMES		
Columbidae:		
Columbia guinea	Triangular-spotted pigeon	1
Columba livia (domestic)	Archangel pigeon	1
Columba livia (domestic)	Fan-tailed pigeon	1
Columba maculosa	Spot-winged pigeon	1

Columbidae—Continued.

Columba palumbus	Wood pigeon	1
Ducula aenea	Green imperial pigeon	1
Goura cristata	Sclater's crowned pigeon	1
Goura victoria	Victoria crowned pigeon	1
Lamprotreron jambu	Pink-headed fruit pigeon	1
Leptotila rufaxilla	Scaled pigeon	1
Muscadivores paulina	Celebian imperial pigeon	1
Streptopelia chinensis	Asiatic collared dove	3
Streptopelia chinensis ceylonensis	Lace-necked or ash dove	6
Streptopelia semitorquata	African red-eyed dove	1
Turtur risorius	Turtledove	7
Tympanistria tympanistria fraseri	Tambourine pigeon	2
Zenaida auriculata	South American mourning dove	11
Zenaidura macroura	Mourning dove	3

PSITTACIFORMES

Psittacidae:

Agapornis pullaria	Red-faced lovebird	12
Ara ararauna	Yellow and blue macaw	3
Ara chloroptera	Red and blue macaw	1
Ara macao	Red, blue, and yellow macaw	2
Ara manilata	Illiger's macaw	1
Ara militaria	Mexican green macaw	1
Ara severa	Severe macaw	1
Aratinga euops	Cuban conure	1
Calyptorhynchus magnificus	Banksian cockatoo	1
Coracopsis nigra	Lesser vasa parrot	1
Cyanopsittacus spixi	Spix's macaw	2
Domicella flavopalliata	Red lory	3
Eclectus pectoralis	Eclectus parrot	2
Eolophus roseicapillus	Roseate cockatoo	2
Eupsittula canicularis	Petz paroquet	1
Kakatoe alba	White cockatoo	2
Kakatoe galerita	Large sulphur-crested cockatoo	3
Kakatoe leadbeateri	Leadbeater's cockatoo	1
Kakatoe moluccensis	Great red-crested cockatoo	1
Kakatoe sulphurea	Lesser sulphur-crested cockatoo	5
Kakatoe tenuirostris	Slender-billed cockatoo	1
Lorius domicella	Rajah lory	2
Lorius garrulus	Lory	2
Melopsittacus undulatus	Grass parakeet	6
Microglossus aterrimus	Great black cockatoo	1
Myopsitta monachus	Quaker paroquet	1
Nandayus nanday	Nanday paroquet	1
Nestor notabilis	Kea	2
Nymphicas hollandicus	Cockatiel	1
Pionites xanthomera	Amazonian caique	2
Psittacula eupatria	Red-shouldered paroquet	4
Psittacula krameri	Kramer's paroquet	4
Psittacula longicauda	Long-tailed paroquet	2
Psittacus erithacus	African gray parrot	2
Tanygnathus muelleri	Mueller parrot	1
Trichoglossus cyanogrammus	Green-naped lory	1

CUCULIFORMES

Cuculidae:		
Centropus sinensis	Sumatran coucal	1
Eudynamis scolopaceus	Koel	1
Gallirex porphyreolophus	Purple-crested plantain eater	1

STRIGIFORMES

Tytonidae:		
Tyto alba pratincola	American barn owl	2
Strigidae:		
Bubo virginianus	Great horned owl	11
Ketupa ketupu	Malay fish owl	1
Otus asio	Screech owl	2
Strix varia varia	Barred owl	6

CAPRIMULGIFORMES

Podargidae:		
Podargus strigoides	Tawny frogmouth	1

CORACIIFORMES

Alcedinidae:		
Dacelo gigas	Kooka burra	2
Halcyon pyrrhopygius	Red-backed kingfisher	1
Halcyon sanctus	Sacred kingfisher	3
Momotidae:		
Momotus lessoni	Motmot	1
Bucerotidae:		
Buceros rhinoceros	Rhinoceros hornbill	1
Bucorvus abyssinicus	Abyssinian ground hornbill	2
Ceratogymna elata	Yellow-casqued hornbill	1
Dichoceros bicornis	Concave casque hornbill	1

PICIFORMES

Ramphastidae:		
Ramphastos carinatus	Sulphur-breasted toucan	3
Ramphastos piscivorus	Toco toucan	3

PASSERIFORMES

Cotingidae:		
Procnias nudicollis	Naked-throated bell bird	1
Rupicola rupicola	Cock of the rock	1
Corvidae:		
Calocitta formosa	Mexican magpie jay	1
Cissa chinensis	Chinese cissa	2
Corvus albus	White-breasted crow	2
Corvus brachyrhynchos	American crow	2
Corvus cornix	Hooded crow	2
Corvus coronoides	Australian crow	1
Corvus cryptoleucus	White-necked raven	4
Corvus insolens	Indian crow	3
Cyanocitta cristata	Blue jay	2
Cyanocorax chrysops	Urraca jay	2
Cyanocorax cyanopogon	White-naped jay	1
Cyanocorax mystacalis	Moustached jay	1

Corvidae—Continued.		
Gymnorhina hypoleuca	White-backed piping crow	3
Pica nuttallii	Yellow-billed magpie	1
Pica pica hudsonia	American magpie	1
Urocissa occipitalis	Red-billed blue magpie	1
Paradiseidae:		
Ailuroedus crassirostris	Australian catbird	1
Epimachus fastuosus	Sickle-billed bird of paradise	1
Ptilonorhynchus violaceus	Satin bowerbird	1
Seleucides niger	12-wired bird of paradise	1
Uranornis rubra	Red bird of paradise	1
Pycnonotidae:		
Otocompsa jocosus	Red-eared bulbul	1
Pycnonotus analis	Yellow-vented bulbul	2
Pycnonotus bindentatus	Orange-spotted bulbul	2
Rubigula dispar	Red-throated bulbul	1
Trachycomus zeylonicus	Yellow-crowned bulbul	1
Turdidae:		
Mesia argentauris	Silver-eared mesia	1
Mimocichla rubripes	Western red-legged thrush	3
Turdus grayi	Bonaparte's thrush	1
Turdus rufiventris	Argentine robin	3
Laniidae:		
Lanius dorsalis	Teita fiscal shrike	1
Sturnidae:		
Cosmopsaris regius	Splendid starling	2
Creatophora cinerea	Wattled starling	1
Galeopsar salvadorii	Crested starling	1
Gracula religiosa	Southern hill mynah	1
Molothrus bonariensis	Shiny cowbird	1
Trupialis defilippi	Military starling	11
Ploceidae:		
Coliuspasser ardens	Red-necked whydah	1
Diatropura procne	Giant whydah	4
Munia maja	White-headed munia	12
Munia molucca	Black-throated munia	11
Munia oryzivora	Java sparrow	25
	White Java sparrow	1
Munia punctulatus	Rice bird or nutmeg finch	5
Ploceus baya	Baya weaver	5
Ploceus intermedius	Black-cheeked weaver	2
Ploceus rubiginosus	Chestnut-breasted weaver	2
Poephila acuticauda	Long-tailed finch	1
Quelea sanguinirostris intermedia	Southern masked weaver finch	8
Steganura paradisea	Paradise whydah	6
Taeniopygia castanotis	Zebra finch	2
Icteridae:		
Agelaius assimilis	Cuban red-winged blackbird	3
Gymnomystax mexicanus	Giant oriole	2
Icterus icterus	Troupial	4
Notiopsar curaeus	Chilean blackbird	8
Xanthocephalus xanthocephalus	Yellow-headed blackbird	3

Fringillidae:		
Amandava amandava	Strawberry finch	27
Coryphospingus cucullatus	Red-crested finch	2
Cyanocompsa argentina	Argentine blue grosbeak	2
Diuca diuca	Diuca finch	2
Lophospingus pusillus	Black-crested finch	4
Melopyrrha nigra	Cuban bullfinch	1
Paroaria cucullata	Brazilian cardinal	5
Passerina ciris	Painted bunting	1
Pheucticus tibialis	Yellow grosbeak	1
Phrygilus fruticeti	Mourning finch	16
Phrygilus gayi	Gay's gray-headed finch	7
Serinus canarius	Canary	1
Sicalis flaveola	Mysto finch	1
Sicalis minor	Lesser yellow finch	6
Spinus psaltria	Arkansas goldfinch	1
Spinus uropygialis	Chilean siskin	3
Sporophila aurita	Hick's seed-eater	2
Sporophila gutturalis	Yellow-bellied seed-eater	2
Tiaris olivacea	Mexican grassquit	1
Uroloncha leucogastroides	Society finch	1
Volatinia jacarini	Blue-black grassquit	1
Zonotrichia capensis	Chingolo	3

REPTILES

Crocodylidae:	LORICATA	
Alligator mississipiensis	Alligator	38
Alligator sinensis	Chinese alligator	3
Caiman latirostris	Broad-snouted caiman	1
Caiman sclerops	Spectacled caiman	3
Crocodylus acutus	American crocodile	1
Crocodylus cataphractus	Narrow-nosed crocodile	1
Crocodylus niloticus	African crocodile	1
Crocodylus palustris	"Toad" crocodile	2
Crocodylus porosus	Salt-water crocodile	1
Osteolaemus tetraspis	Broad-nosed crocodile	2
Agamidae:	SQUAMATA	
Physignathus lesueurii	Lesueur's water dragon	1
Gekkonidae:		
Gecko gecko	Gecko	4
Iguanidae:		
Anolis carolinensis	False chameleon	25
Anolis equestris	Giant anolis	1
Iguana iguana	Iguana	1
Phrynosoma cornutum	Horned lizard	25
Sauromalus obesus	Chuckwalla	2
Sceloporus undulatus	Fence lizard	1
Anguidae:		
Ophisaurus apus	European glass snake	1
Ophisaurus ventralis	Glass snake	3
Helodermatidae:		
Heloderma horridum	Mexican beaded lizard	2
Heloderma suspectum	Gila monster	6

Teiidae:		
Tupinambis nigropunctatus	Tegu lizard	3
Tupinambis rufescens	Red tegu lizard	2
Tupinambis teguixin	Yellow tegu lizard	3
Scincidae:		
Egernia cunninghami	Cunningham's skink	3
Tiliqua nigrolutea	Mottled lizard	2
Tiliqua scincoides	Blue-tongued lizard	2
Varanidae:		
Varanus komodoensis	Komodo dragon	1
Varanus niloticus	African monitor	7
Varanus salvator	Sumatran monitor	10

OPHIDIA

Boidae:		
Boa cookii	Cook's tree boa	1
Constrictor constrictor	Boa constrictor	2
Epicrates cenchris	Rainbow boa	7
Epicrates crassus	Salamanta	1
Epicrates striatus	Haitian boa	2
Python molurus	Indian rock python	3
Python regius	Ball python	1
Python reticulatus	Regal python	2
Python sebae	African rock python	2
Tropidophis melanurus	Cuban boa	1
Colubridae:		
Acrochordus javanicus	Elephant-trunk snake	1
Coluber constrictor	Black snake	2
Cyclagras gigas	Cobra-de-Paraguay	6
Diadophis punctatus	Ring-necked snake	1
Dromicus dorsalis	James Island snake	1
Dromicus sp	South Seymour Island snake	1
Drymarchon corais couperi	Indigo snake	5
Elaphe guttata	Corn snake	3
	Night snake	1
Elaphe obsoleta	Pilot snake	6
	White pilot snake	1
Elphe quadrivittata	Chicken snake	3
Heterodon contortrix	Hog-nosed snake	1
Lampropeltis getulus floridana	Florida king snake	2
Lampropeltis getulus getulus	King or chain snake	1
Lampropeltis triangulum	Milk snake	1
Leimadophis poecilogyrus	South American green snake	1
Liophis miliaris	South American brown snake	1
Liopeltis vernalis	Smooth green snake	1
Natrix cyclopion	Water snake	2
Natrix sp	Water snake	3
Pituophis catenifer	Western bull snake	1
Thamnophis ordinoides	California garter snake	1
Thamnophis sirtalis concinnus	Pacific garter snake	1
Thamnophis sirtalis sirtalis	Garter snake	15
Elapidae:		
Naja hannah	King cobra	1
Naja tripudians sumatrana	Sumatran black-hooded cobra	1
Naja sp	African black cobra	2

Crotalidae:		
Agkistrodon mokasen	Copperhead snake	2
Agkistrodon piscivorus	Water moccasin	1
Crotalus adamanteus	Florida diamond-backed rattlesnake	4
Crotalus cerastes	Sidewinder rattlesnake	7
Crotalus cinereous	Texas rattlesnake	6
Crotalus horridus	Banded rattlesnake	2
Sistrurus miliarius	Pigmy rattlesnake	1
Viperidae:		
Bitis gabonica	Gaboon viper	2
Bitis nasicornis	Rhinoceros viper	1

TESTUDINATA

Chelydidae:		
Batrachemys nasuta	South American side-necked turtle	3
Chelodina longicollis	Australian snake-necked turtle	2
Chelys fimbriata	Matamata turtle	1
Hydrapis sp	South American snake-necked turtle	4
Hydromedusa tectifera	South American snake-necked turtle	16
Platysternidae:		
Platemys platycephala	Flat-headed turtle	1
Platysternum megacephalum	Large-headed Chinese turtle	1
Pelomedusidae:		
Pelomedusa galeata	Common African water tortoise	2
Podocnemis expansa	South American river tortoise	1
Kinosternidae:		
Kinosternon sp	Central American musk turtle	1
Kinosternon subrubrum	Musk turtle	2
Chelydridae:		
Chelydra serpentina	Snapping turtle	8
Macrochelys temminckii	Alligator snapping turtle	1
Testudinidae:		
Chrysemys picta	Painted turtle	13
Clemmys guttata	Spotted turtle	6
Clemmys insculpta	Wood tortoise	3
Clemmys muhlenbergii	Muhlenberg's tortoise	1
Cyclemys amboinensis	Kura kura box turtle	6
Deirochelys reticularia	Chicken tortoise	1
Emys blandingii	Blanding's turtle	1
Gopherus polyphemus	Gopher turtle	1
Graptemys geographica	Geographic turtle	1
Kinixys erosa	West African back-hinged tortoise	4
Malaclemmys centrata	Diamond-back terrapin	9
Pseudemys concinna	Cooter	4
Pseudemys decussata	Haitian terrapin	1
Pseudemys d'orbignyi	D'Orbigny's turtle	3
Pseudemys elegans	Cumberland terrapin	8
Pseudemys floridana	Florida terrapin	2
Pseudemys malonei	Fresh-water turtle	2
Pseudemys ornata	Ornate turtle	2
Pseudemys rubriventris	Red-bellied turtle	1
Pseudemys rugosus	Cuban terrapin	1
Terrapene carolina	Box tortoise	15

Testudinidae—Continued.		
Terrapene ornata	Ornate box turtle	5
Testudo chilensis		9
Testudo denticulata		2
Testudo elegans	Star tortoise	2
Testudo emys	Sumatran land tortoise	1
Testudo ephippium	Duncan Island tortoise	3
Testudo hoodensis	Hood Island tortoise	3
Testudo tornieri	Soft-shelled land tortoise	4
Testudo vicina	Albemarle Island tortoise	3
Trionychidae:		
Amyda ferox	Soft-shelled turtle	6
Amyda triunguis	West African soft-shelled turtle	2
Trionyx cartilagineus	Asiatic soft-shelled turtle	1

AMPHIBIA

CAUDATA

Salamandridae:		
Triturus pyrrhogaster	Red-bellied Japanese newt	1
Triturus torosus	California newt	12
Triturus viridescens	Common newt	2
Triturus vulgaris	Salamander	2
Ambystomidae:		
Ambystoma maculatum	Spotted salamander	2
Megalobatrachus japonicus	Giant salamander	1
Amphiumidae:		
Amphiuma means	Blind eel or Congo snake	2
Amphiuma tridactylum	Blind eel or Congo snake	1

SALIENTIA

Discoglossidae:		
Bombina bombina	Fire-bellied toad	6
Dendrobatidae:		
Atelopus sp	Spotted atelopus	1
Dendrobates auratus	Arrow-poison frog	3
Bufonidae:		
Bufo americanus	Common American toad	1
Bufo empusus	Sapo de concha	12
Bufo marinus	Marine toad	10
Bufo peltocephalus	Cuban giant toad	5
Ceratophrydae:		
Ceratophrys ornata	Horned frog	2
Ceratophrys varius	Horned frog	6
Hylidae:		
Hyla caerulea	Australian tree frog	1
Hyla versicolor	Common tree frog	1
Pipidae:		
Pipa americana	Surinam toad	1
Ranidae:		
Rana catesbiana	American bullfrog	3
Rana clamitans	Green frog	3
Rana occipitalis	West African bullfrog	1

FISHES

Astronotus ocellatus	----------	3
Botia macracanthus	Clown loach	2
Carnegiella strigata	Striped hatchet fish	4
Corydoras melanistius	Armored catfish	5
Epalzeorhynchus talopterus	Black shark	4
Hemigrammus unilineatus	----------	1
Hyphessobrycon innesi	Neon tetra fish	16
Kryptopterus bicirrhus	Glass catfish	4
Lebistes reticulatus	Guppy	25
Lepidosiren paradoxa	South American lungfish	3
Leporinus fasciata	Leopard fish	1
Monocirrhus polyacanthus	Leaf fish	1
Nannostomus anomalus	----------	4
Nannostomus marginatus	----------	2
Nannostomus trilineatus	----------	2
Nannostomus sp	----------	2
Pantodon buchholzi	Butterfly fish	2
Platypoecilus maculatus	Goldplaties	10
Plecostomus sp	Window cleaner	4
Pristella riddlei	----------	3
Pterophyllum scalare	Angel fish	4
Puntius laterstrigga	----------	1
Puntius partipentazona	Red-finned barb	3
Rasbora heteramorpha	Rasbora	8
Serrasalmus ternetzi	Piranha or cannibal fish	1
Tanichthys albonubes	White Cloud Mountain fish	20
Tilapia sp	Mouth-breeding fish	3
Trichogaster leeri	3-spot gourami	3
Xiphophorus helleri	Sword-tail	1
----------	Black knife fish	2

ARACHNIDS

Eurypelma sp	Tarantula	2
Latrodectus mactans	Black widow spider	1

INSECTS

Blabera sp	Giant cockroach	26

MOLLUSKS

Achatina variegata	Giant land snail	5

CRUSTACEANS

Coenobita clypeatus	Land hermit crab	3

Respectfully submitted.

W. M. MANN, *Director.*

Dr. C. G. ABBOT,
Secretary, Smithsonian Institution.

APPENDIX 8

REPORT ON THE ASTROPHYSICAL OBSERVATORY

SIR: I have the honor to submit the following report on the activities of the Astrophysical Observatory for the fiscal year ended June 30, 1941:

WORK AT WASHINGTON

Messrs. Aldrich and Hoover, with assistance of computers Mrs. A. M. Bond, Miss L. Simpson, and Miss N. M. McCandlish, prepared in manuscript the immense table of daily solar-constant observations from 1923 to 1939. The table contains all individual observations in detail for the three stations, Montezuma, Table Mountain, and Mount St. Katherine. A single day sometimes involves in itself alone a subtable of 10 lines, 10 columns wide. Every solar-constant determination was scrutinized in detail from the original records before entry into the great table, and in very many instances recomputed to check discordant results. Mean values giving the most probable result of each day at each station were computed, and all were plotted on an extended scale. This plot made up a roll about 15 inches wide and 200 feet long.

In this form every day's values were scrutinized by C. G. Abbot, and discordances noted. As one result of his work in preparation of a paper entitled "An Important Weather Element Hitherto Generally Disregarded,"[1] Dr. Abbot had been strongly impressed by the fact that the solar variation is several times greater in percentage for blue-violet rays than for total radiation. This led him to investigate whether on discordant days the shorter wave length parts of the energy spectrum of the sun, as computed for outside our atmosphere, were also discordant. It proved that in many cases they were not, showing that errors had been made in other than the spectral parts of the determinations. Hence, the entire great table was gone through, and for all discordant days the blue-violet extra-atmospheric spectrum was reduced to comparable units by bringing all days to equality in the infrared region, where solar variation is nearly nil. Nearly a hundred pages of newly computed manuscript tables were required to set forth this information.

With this new information available, Dr. Abbot in many cases marked "improved preferred" daily values on the great chart for one

[1] Smithsonian Misc. Coll., vol. 101, No. 1, 1941.

or more of the stations, as dictated by the blue-violet spectrum. He then took the general mean for each day, not only of the untreated results, taking into account only the grades assigned by Messrs. Aldrich and Hoover for the separate stations, but also an "improved preferred" mean for perhaps one-fourth of all the days. These new means were the results preferred after considering the blue-violet spectrum. Both of these daily means were entered in the great table, so that when it is published, readers may use either the preferred general mean or the "improved preferred" general mean, as they please.

As the great table was thus being finished in manuscript, it was being typewritten by Miss M. A. Neill in preparation for the printer. By the end of the fiscal year it was almost finished for publication. In the meantime the rest of the manuscript for volume 6 of the Annals had been finished as far as possible by Dr. Abbot and typed by Miss Neill. But some changes and additions will be made after the inspection of the great table is completed. There appears every reason to hope that the entire manuscript of volume 6, including the great table and its subsidiaries, tables of 10-day and monthly means, will be in the printer's hands before New Year's Day.

The study of the great table led Dr. Abbot to reconsider whether the sun's variation might not be more effectively followed by observations limited to the blue-violet region of spectrum. He was at length able to devise a method which appears promising, and which has been introduced just at the end of the fiscal year at all three field stations. In brief, the method contemplates inserting in front of the spectrobolometer slit a glass filter which restricts the radiation to the desired blue-violet region. An exactly similar glass filter is inserted before the aperture of the pyrheliometer. Knowing from the usual solar-constant work of the day the atmospheric transmission coefficients for blue-violet rays, it is possible to compute the extra-atmospheric energy spectrum of the restricted blue-violet spectrum given by the screened spectrobolometer. A comparison of the blue-violet energy spectra at the station and as computed for outside the atmosphere gives a factor to multiply the screened pyrheliometer reading to what it would be outside the atmosphere.

In this way we restrict the observations to the most variable part of the observed solar spectrum, and avoid those spectral regions where ozone, water vapor, and extreme short and long wave lengths introduce great errors. We greatly hope that this new method will yield more reliable daily indications of the solar variation.

The necessary instrumental changes for introducing the new method were done by A. Kramer. He has also prepared special apparatus for solar distillation of sea water after Dr. Abbot's design, and many other required small jobs for the Observatory.

Dr. H. Arctowski continued his meteorological investigations relating to the effects of solar variation on atmospheric barometric pressure and temperature. His studies led to researches on the upper air. By courtesy of the Chief of the United States Weather Bureau a long series of daily nocturnal radio-meteorograph records were procured. Dr. Arctowski did very extensive computations and graphical representations with these data. At the end of about 18 months of strenuous investigation he prepared a paper illustrated by many plots and much tabular matter which will be found of source value hereafter. This paper will soon issue under a Roebling grant. Dr. Arctowski finds the important influence of solar variation on weather plainly obvious, but the manner of its operation extremely complex. He regards this first paper as merely introductory, and sees a great field for future investigation.

FIELD STATIONS

As far as possible daily determinations of the solar constant of radiation were made at three field stations, Montezuma, Chile, Table Mountain, Calif., and Tyrone, N. Mex. A commodious reinforced concrete dwelling house was erected at Montezuma under H. B. Freeman's direction.

PERSONNEL

L. A. Fillmen, for many years instrument maker in the Division of Radiation and Organisms under private support at the Smithsonian Institution, was transferred to the Astrophysical Observatory Government roll.

SUMMARY

The immense task of preparing the solar-constant work of the past 20 years for final publication was practically finished. A new method of following solar variation was devised and installed at all field stations. An extensive research on the effects of solar variation by Dr. H. Arctowski approached publication. Dr. Abbot published a paper entitled "An Important Weather Element Hitherto Generally Disregarded," in which many proofs of solar variation were assembled, and the effects of it on weather were shown, together with preliminary attempts at 3- to 5-year weather forecasts and verifications. These ambitious forecasts, while not as successful as was hoped, are promising.

Respectfully submitted.

C. G. Abbot, *Director.*

The Secretary,
Smithsonian Institution.

APPENDIX 9

REPORT ON THE DIVISION OF RADIATION AND ORGANISMS

SIR: I have the honor to submit the following report on the activities of the Division of Radiation and Organisms during the year ended June 30, 1941:

The operations of the Division have been financially supported by funds of the Smithsonian Institution and in part by a grant from the Research Corporation of New York.

For several months during the past year actual work in the laboratories was suspended during the construction of a new sewer system and the preparation and actual work of electrical rewiring throughout the building. Also three of the laboratories and the machine shop were repainted.

Considerable time has been given by members of the division in the planning and construction of an exhibit now on display as part of the "Index Exhibit" in the Main Hall of the Smithsonian Building. A detailed description of this exhibit appears in the July 1941 number of the Scientific Monthly.

INFLUENCE OF RADIATION ON RESPIRATION

Following the preliminary experiments and improvement in technique as reported last year on the project dealing with the genesis of chlorophyll and the beginning of photosynthesis, many data have been obtained on the respiration of etiolated barley seedlings. This information is highly desirable because of its bearing upon photosynthesis as measured by the gaseous exchange method. Furthermore, a comprehensive review of the literature on respiration as affected by radiation is being completed and will soon be made available.

The rate of respiration (carbon dioxide evolution) of etiolated barley seedlings (i. e., seedlings grown in complete darkness and devoid of chlorophyll) increases following illumination, whether measured in dark or in light. Under favorable conditions this rise amounts to as much as 20 percent of the previous dark rate and is maintained for at least 7 hours after the light exposure.

The maximal effect of illumination for a 30-minute period occurs at a fairly low intensity (60 foot-candles or less). The magnitude of the effect produced by 60 foot-candles of light increases with the time of illumination up to an exposure period of about 20 minutes and remains constant with longer light periods. These results are graphically illustrated in figure 1.

In many of these studies it was observed that the rate of respiration was not as constant as one would desire during the periods prior to irradiation. It was thought that perhaps the metabolic reactions of the seedling were affected in transferring them from the germination conditions to those of the respiration chamber. A

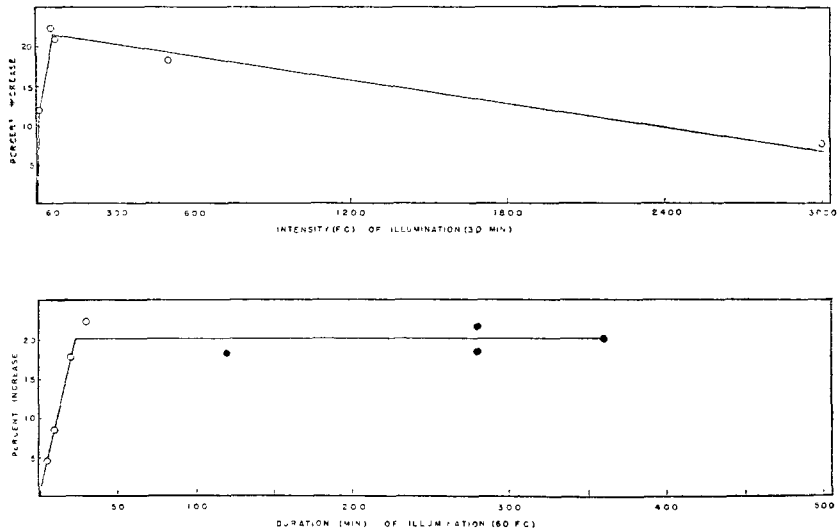


FIGURE 1.—Effect of illumination on respiration of etiolated barley seedlings. Percentage increase in rate of respiration is plotted against intensity of illumination in upper graph and against duration of exposure in lower graph.

number of changes were made in the germination conditions and in the preliminary treatment of the experimental plants in the respiration chamber. After many experiments of this nature it appears that the rate of respiration either increases or decreases continuously for a period of time following exposures of the seedlings to low or high carbon dioxide concentrations respectively. For example, figure 2 shows the relative rates of respiration for successive half-hour periods following a conditioning period of 5 percent carbon dioxide.

From data of this type it would appear that conditions of carbon dioxide storage or depletion develop in the plant tissue depending upon the concentration of this gas surrounding the plants. In subsequent periods, when the respiration is measured there is an increase or decrease in the rate of CO_2 excretion (i. e., in the apparent

rate of respiration) until a state of equilibrium with the new environment is attained. If this phenomenon is of widespread occurrence in green plants as well, it must be of considerable importance also in experiments in which rates of photosynthesis are measured.

Considerable time has been spent during the late winter and spring in improving the performance of the spectrograph used in measuring carbon dioxide for very short periods. A 15-cc. volume absorp-

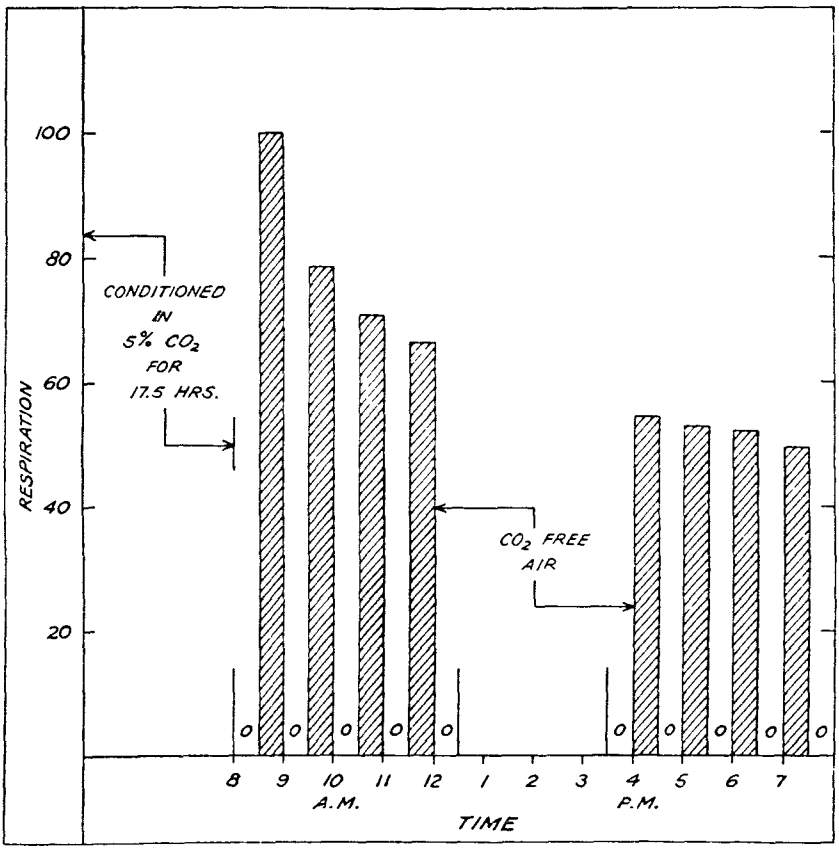


FIGURE 2.—Effect of previous CO_2 environmental conditions on succeeding rates of respiration of etiolated barley seedlings.

tion cell providing a 15-cm. optical path was made in the shop and installed on the instrument. The spectrograph case was lagged with 4 inches of rock wool and the whole room thermostated to maintain a temperature of 30° C. These features have improved the speed-sensitivity and stability of the set-up very materially. The assembly has been used recently in measuring the solubility of CO_2 in water at very low concentrations where a marked departure from Henry's Law was discovered. Further experiments on this are in progress and will be published soon along with a detailed description of the spectrographic method of CO_2 measurement.

INFLUENCE OF LIGHT IN EARLY GROWTH OF GRASS SEEDLINGS

Further study of the spectral effectiveness of radiation for the growth inhibition of the oats mesocotyl has indicated that the maximum response occurs at 6600 A. It is highly suggestive that both chlorophyll *a* and a pigment as yet unidentified which has been found in dark-grown oats seedlings exhibit an absorption band at this position.

A comparative study has been undertaken of some other species of grasses that have been reported in the literature as having mesocotyls insensitive to light. All of those so far investigated have been found to be suppressed by light although the intensities required are much greater than in the case of *Avena*.

Since the growth of the oats mesocotyl is decreased, even in darkness, by higher temperatures it is of interest to compare the effects of temperature and of radiation. The high temperature inhibition appears to differ fundamentally from the light inhibition inasmuch as the growth of other organs of the seedling, notably the roots, is also greatly suppressed in the former case. Some preliminary experiments have indicated that in certain varieties of rice, on the other hand, mesocotyl growth is greater at higher temperatures.

INFLUENCE OF CULTURAL CONDITIONS ON THE GROWTH OF ALGAE

The influence of culture conditions on the photosynthetic behavior of the alga *Chlorella pyrenoidosa* has been subjected to further investigation. The growth cycle of this organism has been studied in relation to light intensity, carbon dioxide concentration, and the composition of the nutrient solution. This work is far from complete but has suggested certain changes in the composition of the nutrient solution and in the design of the apparatus. Equipment is being constructed for the continuous culture of algae in order to obtain completely reproducible quantities of biological material for irradiation experiments.

Experiments were also conducted to ascertain suitable light conditions and culture media for optimum growth of the alga *Haematococcus pluvialis* in preparation for research on the comparative effects of short wave lengths of the ultraviolet on the green pigment, chlorophyll, and the red pigment, haematochrome, in algae.

As a result of inquiries regarding the use of algae in industry and because of its importance to producers of kelp, Irish moss, agar, and alginic acid in the defense program, a paper is being prepared containing the latest statistics and information about the economic uses of algae.

PERSONNEL

No changes have occurred in the status of the Division's personnel during the past year. Dr. Jack E. Myers has continued his work with algae and on photosynthesis under his National Research Fellowship grant.

PAPERS PRESENTED AT MEETINGS

Photosynthesis and fluorescence. Presented by E. D. McAlister at the Marine Biological Station, Pacific Grove, Calif., and at Stanford University, Palo Alto, Calif., in August 1940.

Quantum efficiency of photosynthesis from fluorescence measurements. Presented by E. D. McAlister before the Physics Colloquium, George Washington University, Washington, D. C., on October 23, 1940.

Fluorescence and photosynthesis. Presented by E. D. McAlister before the Philosophical Society of Washington, D. C., on October 26, 1940.

The efficiency of photosynthesis in relation to fluorescence. Presented by E. D. McAlister before the Botanical Society of America, Philadelphia, Pa., December 30, 1940.

Inhibition of first internode of *Avena sativa* by radiation. Presented by Robert L. Weintraub before the American Society of Plant Physiologists, Philadelphia, Pa., December 30, 1940.

Influence of light on the respiration of etiolated barley seedlings. Presented by Earl S. Johnston and Robert L. Weintraub before the American Society of Plant Physiologists, Philadelphia, Pa., December 30, 1940.

Culture conditions for *Chlorella* in relation to its photosynthetic behavior. Presented by Jack Myers before the American Society of Plant Physiologists, Philadelphia, Pa., December 30, 1940.

Photosynthesis in past ages. Presented by E. D. McAlister before the Paleontological Society of Washington in April 1941.

PUBLICATIONS

CHASE, FLORENCE MEIER. Increased stimulation of the Alga *Stichococcus bacillaris* by successive exposures to short wave lengths of the ultraviolet. Smithsonian Misc. Coll., vol. 99, No. 17, pp. 1–16, 1941.

MCALISTER, E. D., and MYERS, JACK. The time course of photosynthesis and fluorescence observed simultaneously. Smithsonian Misc. Coll., vol. 99, No. 6, pp. 1–37, 1940.

MCALISTER, E. D., and MYERS, JACK. Time course of photosynthesis and fluorescence. Science, vol. 92, No. 2385, pp. 241–243, 1940.

MCALISTER, E. D., MATHESON, G. L., and SWEENEY, W. J. A large recording spectrograph for the infrared to 15μ. Rev. Scientific Instr., vol. 12, No. 6, pp. 314–319, 1941.

MEIER, FLORENCE E. Plankton in the water supply. Ann. Rep. Smithsonian Inst. for 1939, pp. 393–412, 1940.

WEINTRAUB, ROBERT L. Plant-tissue cultures. Ann. Rep. Smithsonian Inst. for 1940, pp. 357–368, 1941.

Respectfully submitted.

EARL S. JOHNSTON, *Assistant Director.*

Dr. C. G. ABBOT,
Secretary, Smithsonian Institution.

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APPENDIX 10

REPORT ON THE LIBRARY

SIR: I have the honor to submit the following report on the activities of the Smithsonian library for the fiscal year ended June 30, 1941:

THE LIBRARY

The library, or library system, of the Smithsonian is made up of 10 major and 35 minor units. The former consist of the main library of the Institution, which since 1866 has been in the Library of Congress and is known as the Smithsonian Deposit; the libraries of the United States National Museum, Bureau of American Ethnology, Astrophysical Observatory, Freer Gallery of Art, National Collection of Fine Arts, National Zoological Park, Division of Radiation and Organisms; the Langley Aeronautical Library—deposited in 1930 in the Division of Aeronautics at the Library of Congress—and the Smithsonian office library. The minor units are the sectional libraries of the National Museum. Although the collections in these 45 libraries are on many subjects, they have to do chiefly with the matters of special moment to the Institution and its branches, namely, the natural and physical sciences and technology and the fine arts. They are particularly strong in their files of standard monographs and serials and of the reports, proceedings, and transactions of the learned institutions and societies of the world.

Cooperating with the Smithsonian library system, but independent of it, is the library of the National Gallery of Art, which, during the year just closed took its first steps, under a competent staff, to meet the reference needs of the Gallery personnel and of others outside. The libraries of the Institution welcome the opportunity to further, in every way possible, the interests of this new friendly neighbor.

PERSONNEL

The year brought an unusually large number of changes in the staff. Among these were the following: The retirement, on account of age, of Miss Gertrude L. Woodin, after long and valuable service as assistant librarian; the promotion of Miss Elisabeth P. Hobbs,

junior librarian, to succeed her, and the transfer of Miss Anna Moore Link from the editorial office in the Bureau of American Ethnology to the vacancy thus created; the advancement of Miss Nancy Alice Link to the position of editorial assistant in the Bureau; the resignation of Mrs. Dorothy E. Goodrich, under library assistant, and the selection of Miss Elizabeth Gordon Moseley as her successor. The position of minor library assistant was reclassified to that of junior clerk-typist and filled by the appointment of Miss Elizabeth Harriet Link. Charles McDowell served part of the year as assistant messenger. The temporary employees were Mrs. Georgeanna H. Morrill, library assistant, Mrs. Elizabeth C. Bendure, assistant clerk-stenographer, Miss Anna May Light, junior clerk-stenographer, Mrs. Marie Boborykine, special library assistant, and Arthur W. Gambrell, assistant messenger.

EXCHANGE OF PUBLICATIONS

The exchange work of the library was again carried on with the greatest difficulty, owing to abnormal world conditions. The packages received through the International Exchange Service were only 515—fewer by 814 even than those of the year before, when there had been a similar decrease from the normal number; the packages that came by mail were 17,038, or 3,283 fewer than came the previous year. Most of the publications that failed to come were, of course, European and Asiatic. Fortunately, some of these are being held by the issuing agencies, to be sent to the library as soon as the wars are over; others have merely delayed publication; but a few have been discontinued. Altogether the influence of the disturbed conditions that prevailed was far from favorable to the increase and diffusion of knowledge by means of the exchange of learned publications.

There were received, however, a number of rather large sendings, notably from the Clube Zoologico do Brasil, São Paulo; Bataviaasch Genootschap van Kunsten en Wetenschaffen, Batavia; Royal Swedish Academy of Letters, Stockholm; Royal Society of Edinburgh, Edinburgh; Royal Society of Tasmania, Hobart; and Wellington Acclimatisation Society, Wellington.

Dissertations came from only 4 universities, 2 of which are in a neutral European country—Basel and Zürich; and 2 in the United States—Johns Hopkins and Pennsylvania. These totaled 452—quite a contrast to the 5,190 received in 1939 from 34 foreign institutions and 3 American. Of the 452 dissertations 261 were assigned to the Smithsonian Deposit, and the rest, being on medical subjects, were turned over, as usual, to the library of the Surgeon General.

Most of the 2,316 letters written by the staff pertained to the exchange interests of the library. They naturally showed a decrease from 1940, as did the new exchanges arranged for. There were 284 of the latter, however, nearly all of which were on behalf of the Smithsonian Deposit and the libraries of the National Museum, National Collection of Fine Arts, and Astrophysical Observatory. Although the number of want cards handled—795—was smaller by 87 than the year before, the publications obtained, both by special correspondence and by search among the recently organized and listed duplicates in the west stacks of the Institution, were 8,824, or 1,278 more than in 1940. The result of this successful effort was that a great many gaps—some of long standing—were filled in several of the Smithsonian libraries. In addition to these publications, which were assigned to the regular sets, others to the number of 6,112 were selected from the duplicate material and put in reserve for use in the future. Among these were many foreign items—not a few of them rare—closely related to the work of the Institution and its branches. Thus again did the surplus collection in the west stacks prove of no little value to the library system. And it bids fair to prove so for years to come, as this rich store of material is made increasingly available through listing and through checking against the needs of the various libraries.

From time to time, too, during the year files of serials, long and short, not wanted by the libraries were exchanged for publications that otherwise would have had to be purchased. This plan of exchanging duplicates for other publications essential to the Institution was adopted by the library some years ago and has met with much success. It has added to the collections many valuable items and has placed a considerable number in other research institutions where, instead of standing useless on the Smithsonian shelves, they have contributed their part toward the advancement of knowledge. The year just closed brought to the library, under this special exchange plan, a goodly number of important monographs and serials that could not be obtained by regular exchange. Among them were such works as Drawings in the Fogg Museum of Art, vols. I–III, by Agnes Mongan and Paul J. Sachs; The Material Basis of Evolution, by Richard Goldschmidt; The Ferns and Fern Allies of Wisconsin, by R. M. Tryon, Jr., N. C. Fassett, D. W. Dunlop, and M. E. Diemer; and Nomenclator Zoologicus, in 4 volumes, edited by Sheffield A. Neave.

In connection with both its regular and its special exchange activities, the library continued its effort, in cooperation with the offices of publications, to replenish the depleted stock of Smithsonian publications by encouraging the return of material from

libraries throughout the country in which it was not needed. It also continued to act as a clearing-house, thus sending out again much of this material to institutions that were waiting for it. The libraries of more than 25 museums, colleges, and universities eagerly shared in this give and take effort, which was to the advantage of all participants, but chiefly of the Smithsonian library, for by this means it was able not only to make many of the publications of the Institution more widely available to readers and investigators, but to increase in no small measure the supply of such publications—some of which had long been out of print—that could be used for future exchanges.

GIFTS

Many gifts came to the library during the year. Among these were 622 publications from the Geophysical Laboratory of the Carnegie Institution of Washington; 612 from the American Association for the Advancement of Science; 72 from the American Association of Museums; 66 from the Public Library of the District of Columbia; 42 from the National Institute of Health; and 94 from the recently discontinued Bureau of the International Catalogue of Scientific Literature. Among them, too, were a large number of publications from the Honorable Usher L. Burdick, Member of Congress from North Dakota, from the late Mrs. Charles D. Walcott—always a generous friend of the library—and from the Secretary and Assistant Secretary and other members of the Smithsonian staff. The largest gift, however, came from Mrs. Frederick E. Fowle—that of 942 scientific books and journals which had belonged to her husband, the late research assistant of the Astrophysical Observatory.

Other gifts were Hiroshige, by Yoné Noguchi, from the Japanese Embassy; The Herbarist, Nos. 1–7 (1935–1941), from Mrs. Foster Stearns; Chinese Jade Carvings of the Sixteenth to the Nineteenth Century in the Collection of Mrs. Georg Vetlesen—an illustrated descriptive record compiled by Stanley Charles Nott, volume III, from Mrs. Georg Vetlesen; A Catalogue of Rare Chinese Jade Carvings (2 copies), compiled by Stanley Charles Nott, from the compiler; Two Early Portraits of George Washington Painted by Charles Willson Peale, by John Hill Morgan, from the Princeton University Press; Bird Reserves, by E. C. Arnold, from the author; Moss Flora of North America North of Mexico, volume II, part 4, by Dr. A. J. Grout, from the author; The Young Mill-Wrights & Miller's Guide (1807), by Oliver Evans, from Edna E. Switzer; Charles Goodyear—Connecticut Yankee and Rubber Pioneer—A Biography, by P. W. Barker, from Godfrey L. Cabot, Inc.; The Shorter

Scientific Papers of Lee Barker Walton, with an Introduction by Herbert Osborn, edited by George P. Faust, from the editor; Genus Labordia, Hawaiian Euphorbiaceae, Labiatae and Compositae, by Dr. Earl Edward Sherff, from the author; Seventh Report of the Chester County Cabinet of Natural Science (1834), from Dr. Robert B. Gordon; Barbed Fencing, by Charles G. Washburn—a typewritten copy of an original in the possession of the donor, Reginald Washburn, who had the copy made especially for the Smithsonian Institution; Atlanta City Directory, 1940, from the Carnegie Library, Atlanta; Men and Volts, by John Winthrop Hammond, from the General Electric Company; The Cranial Bowl, by Dr. William G. Sutherland, from the author; Military Medals and Insignia of the United States, by J. McDowell Morgan, from the author; The Stapelieae, in 3 volumes, by Alain White and Boyd L. Sloane, from Alain White; The Old Bay Line, by Alexander Crosby Brown, from the Mariners' Museum, Newport News; By Their Works, by H. Phelps Clawson, from the Buffalo Museum of Science; and Flora of Indiana, by Charles C. Deam, from the Indiana Department of Conservation.

SOME STATISTICS

The accessions to the libraries were as follows:

Library	Volumes	Pamphlets and charts	Total	Approximate holdings June 30, 1941
Astrophysical Observatory	173	138	311	10,156
Bureau of American Ethnology	378		378	[1] 33,140
Freer Gallery of Art	398	66	464	16,225
Langley Aeronautical	32	20	52	3,550
National Collection of Fine Arts	240	157	397	7,689
National Museum	1,979	942	2,921	219,760
National Zoological Park	36	34	70	3,916
Radiation and Organisms	67	2	69	596
Smithsonian Deposit, Library of Congress	1,350	758	2,108	568,662
Smithsonian office	65	4	69	30,961
Total	4,718	2,121	6,839	894,655

[1] From this total have been omitted a large collection of pamphlets hitherto included in the holdings reported for the library of the Bureau of American Ethnology, and quite a number of other publications recently removed from the library as not being closely related to the work of the Bureau.

The staff cataloged 6,693 volumes, pamphlets, and charts; prepared and filed 40,238 catalog and shelf-list cards; made 22,311 periodical entries; loaned 10,990 publications to the members of the Institution and its bureaus; and conducted an interlibrary loan service with 45 libraries outside the Smithsonian system. They rendered more reference and bibliographical assistance than ever before, in response to requests in person, by telephone, and by mail, from the staff of the Smithsonian, other Government employees, visitors,

and correspondents far and near—requests often involving hours of search not only at the Institution but at the Library of Congress and elsewhere. They kept the index of Smithsonian publications up to date, and made considerable progress with the index of Smithsonian explorations begun the previous year, and some with that of exchange relations. Their work on the union catalog may be summarized as follows:

Volumes cataloged	2,472
Pamphlets and charts cataloged	1,947
New serial entries made	178
Typed cards added to catalog and shelf list	3,880
Library of Congress cards added to catalog and shelf list	13,662

OTHER ACTIVITIES

As has already been suggested, one of the main activities of the staff, apart from their routine duties, was that of making lists of the longer runs of surplus items in the west stacks and checking them against the needs of the Smithsonian libraries. Another task was that of bringing nearly to completion the checking of the serial holdings of several of the libraries, to be included in the forthcoming second edition of the Union List of Serials. When this work is finished, it will have involved the examination of the records of more than 7,000 sets of serial publications, not including, of course, the thousands in the Smithsonian Deposit and the Langley Aeronautical Library, which, as they are housed in the Library of Congress, are reported by that Library. Still another task was selecting consignments of duplicates for exchange, especially with such universities as Brown, Columbia, Harvard, Pennsylvania, Princeton, and Yale. And another was preparing the exhibition set of Smithsonian publications—by completing it and having many of its volumes bound—for transfer to the shelves provided for it as an outstanding part of the exhibit of Smithsonian interests in the "Diffusion of Knowledge" room at the Institution. And, finally, among other tasks were the following: Sending a large number of foreign documents, which had come to light in course of checking the surplus material, to the Library of Congress; sorting 2,500 or more reprints by subject and assigning them to the appropriate sectional libraries of the National Museum; carrying forward the inventorying of the technological library, with revision of its catalog and shelf list, and the rearranging of the office library; and continuing, with excellent results, the work of reorganizing the library of the Bureau of American Ethnology.

BINDING

Again, lack of funds seriously limited the libraries in meeting their binding needs. This was true in respect both to the thousands of

older serial volumes still standing unbound on the shelves and to hundreds of new ones added the last fiscal year. As it was, the library of the National Museum sent to the bindery 800 volumes; that of the Astrophysical Observatory, 50; of the National Collection of Fine Arts, 59; of the Freer Gallery of Art, 38; and of the National Zoological Park, 11—a total of 958, only about one-half the number of volumes completed during the year by these libraries.

NEEDS

First among the needs, then, is adequate funds for binding, to the end that the publications—some of them almost priceless now, in the light of the destruction that is taking place abroad—may be safeguarded for the permanent use of the Institution.

Another need, which has become acute, is that of more shelf room for the collections, especially those of the National Museum library. Unless this can soon be provided, it may be necessary to resort to the unfortunate measure of placing some of the less-used files in dead storage.

And, finally, five new positions should be established, for the following: An assistant librarian, to take charge of the acquisition department; a junior librarian and a library assistant to strengthen the under-staffed preparation department, especially the catalog division; a junior typist, to relieve the catalogers of much clerical routine; a messenger, to serve primarily the libraries of the Institution proper.

Respectfully submitted.

WILLIAM L. CORBIN, *Librarian.*

DR. C. G. ABBOT,
Secretary, Smithsonian Institution.

APPENDIX 11

REPORT ON PUBLICATIONS

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and the Government branches under its administrative charge during the year ended June 30, 1941:

The Institution published during the year 16 papers in the Smithsonian Miscellaneous Collections series, and title page and table of contents of volume 98; 1 annual report and pamphlet copies of 27 articles in the report appendix; and 3 special publications.

The United States National Museum issued 1 annual report; 19 Proceedings papers, and title page, table of contents, and index of volume 86; 1 Bulletin, and 1 volume and 1 part of a volume of Bulletin 100; and title page, table of contents, and index of volume 26 of Contributions from the United States National Herbarium.

The National Collection of Fine Arts issued 1 catalog, and the Freer Gallery of Art, 1 pamphlet.

The Bureau of American Ethnology issued 1 annual report and 3 bulletins.

Of the publications there were distributed 125,837 copies,[1] which included 66 volumes and separates of the Smithsonian Contributions to Knowledge, 32,031 volumes and separates of the Smithsonian Miscellaneous Collections, 24,022 volumes and separates of the Smithsonian annual reports, 5,243 Smithsonian special publications, 52,170 volumes and separates of the National Museum publications, 11,882 publications of the Bureau of American Ethnology, 9 publications of the National Collection of Fine Arts, 3 publications of the Freer Gallery of Art, 16 reports on the Harriman Alaska Expedition, 12 Annals of the Astrophysical Observatory, and 383 reports of the American Historical Association.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

There were issued title page and table of contents of volume 98, and 15 papers of volume 99 and 1 paper of volume 101, making 16 papers in all, as follows:

VOLUME 98

Title page and table of contents. (Publ. 3590.)

[1] This does not include the Brief Guide to the Smithsonian Institution, the catalog of the National Collection of Fine Arts, or the pamphlet of the Freer Gallery of Art.

VOLUME 99

No. 6. The time course of photosynthesis and fluorescence observed simultaneously, by E. D. McAlister and Jack Myers. 37 pp., 16 figs. (Publ. 3591.) August 28, 1940.

No. 7. A systematic classification for the birds of the world, by Alexander Wetmore. 11 pp. (Publ. 3592.) October 10, 1940.

No. 9. Recent Foraminifera from Old Providence Island collected on the Presidential Cruise of 1938, by Joseph A. Cushman. 14 pp., 2 pls. (Publ. 3594.) January 24, 1941.

No. 10. Coelenterates collected on the Presidental Cruise of 1938, by Elisabeth Deichmann. 17 pp., 1 pl., 4 figs. (Publ. 3595.) January 27, 1941.

No. 11. A new cephalopod mollusk from the Presidential Cruise of 1938, by Helen C. Stuart. 6 pp., 2 figs. (Publ. 3596.) February 4, 1941.

No. 12. Acarina collected on the Presidential Cruise of 1938, by G. W. Wharton. 8 pp., 4 figs. (Publ. 3597.) January 29, 1941.

No. 13. Euphausiacea and Mysidacea collected on the Presidential Cruise of 1938, by W. M. Tattersall. 7 pp., 2 figs. (Publ. 3598.) January 31, 1941.

No. 14. The male genitalia of Hymenoptera, by R. E. Snodgrass. 86 pp., 33 pls., 6 figs. (Publ. 3599.) January 14, 1941.

No. 15. Evidence of early Indian occupancy near the Peaks of Otter, Bedford County, Virginia, by David I. Bushnell, Jr. 14 pp., 5 pls., 4 figs. (Publ. 3601.) December 23, 1940.

No. 16. New fossil lizards from the Upper Cretaceous of Utah, by Charles W. Gilmore. 3 pp., 2 figs. (Publ. 3602.) December 9, 1940.

No. 17. Increased stimulation of the alga *Stichococcus bacillaris* by successive exposures to short wave lengths of the ultraviolet, by Florence Meier Chase. 16 pp., 2 pls., 3 figs. (Publ. 3603.) January 10, 1941.

No. 18. Two new races of passerine birds from Thailand, by H. G. Deignan. 4 pp. (Publ. 3605.) December 11, 1940.

No. 19. Notes on Mexican snakes of the genus *Geophis*, by Hobart M. Smith. 6 pp. (Publ. 3629.) February 19, 1941.

No. 20. Further notes on Mexican snakes of the genus *Salvadora*, by Hobart M. Smith. 12 pp., 7 figs. (Publ. 3630.) February 21, 1941.

No. 21. A new shipworm from Panama, by Paul Bartsch. 2 pp., 1 pl. (Publ. 3632.) March 31, 1941.

VOLUME 101

No. 1. An important weather element hitherto generally disregarded, by C. G. Abbot. 34 pp., 11 figs. (Publ. 3637.) May 27, 1941.

SMITHSONIAN ANNUAL REPORTS

Report for 1939.—The complete volume of the Annual Report of the Board of Regents for 1939 was received from the Public Printer in October 1940.

Annual Report of the Board of Regents of the Smithsonian Institution showing the operations, expenditures, and condition of the Institution for the year ended June 30, 1939. xiii+567 pp., 139 pls., 58 figs. (Publ. 3555.)

The appendix contained the following papers:

Is there life in other worlds? by H. Spencer Jones, F. R. S.
Use of solar energy for heating water, by F. A. Brooks.
The fringe of the sun: nebulium and coronium, by C. G. James.
Our knowledge of atomic nuclei, by G. P. Harnwell, Ph. D.
Spectroscopy in industry, by George R. Harrison, Ph. D.
Physical science in the crime-detection laboratory, by J. Edgar Hoover.
Physical interpretation of the weather, by Edgar W. Woolard.
Hurricanes into New England: meteorology of the storm of September 21, 1938, by Charles F. Brooks.
Humanity in geological perspective, by Herbert L. Hawkins, D. Sc., F. R. S., F. G. S.
Geologic exhibits in the National Zoological Park, by R. S. Bassler.
The structure of the earth as revealed by seismology, by Ernest A. Hodgson.
Our petroleum supply, by Hugh D. Miser.
Biologic balance on the farm, by W. L. McAtee.
On the frontier of British Guiana and Brazil, by Capt. H. Carington Smith, R. E.
The sea bird as an individual: results of ringing experiments, by R. M. Lockley.
Birds and the wind, by Neil T. McMillan.
Bookworms, by E. A. Back.
The problem of conserving rare native plants, by M. L. Fernald, D. C. L., D. Sc.
Plankton in the water supply, by Florence E. Meier.
Trichinosis in swine and its relationship to public health, by Benjamin Schwartz.
Closing the gap at Tepe Gawra, by E. A. Speiser.
Sun worship, by Herbert J. Spinden.
The use of soapstone by the Indians of the eastern United States, by David I. Bushnell, Jr.
The modern growth of the totem pole on the northwest coast, by Marius Barbeau.
Historic American highways, by Albert C. Rose.
Modern trends in air transport, by W. F. Durand.
The story of the Time Capsule, by G. Edward Pendray.

Report for 1940.—The report of the Secretary, which included the financial report of the executive committee of the Board of Regents, and which will form part of the annual report of the Board of Regents to Congress, was issued in January 1941.

Report of the Secretary of the Smithsonian Institution and financial report of the executive committee of the Board of Regents for the year ended June 30, 1940. ix+115 pp., 4 pls.

The report volume, containing the general appendix, was in press at the close of the year.

SPECIAL PUBLICATIONS

Brief guide to the Smithsonian Institution (fourth edition). 80 pp., 74 figs. (Publ. BL.) July 1, 1940.

The Smithsonian Institution, by C. G. Abbot. 25 pp., 13 pls., (Publ. 3604.) January 18, 1941.

Explorations and field work of the Smithsonian Institution in 1940. 100 pp., 100 halftone figs. (Publ. 3631.) April 3, 1941.

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The editorial work of the National Museum has continued during the year under the immediate direction of the editor, Paul H. Oehser. There were issued 1 annual report; title page, table of contents, and index of volume 86 of the Proceedings, and 19 separate Proceedings papers from volumes 87, 88, 89, and 90; 1 Bulletin, and 1 volume and 1 part of a volume of Bulletin 100; and title page, table of contents, and index of volume 26 of Contributions from the United States National Herbarium, as follows:

MUSEUM REPORT

Report on the progress and condition of the United States National Museum for the year ended June 30, 1940. iii+118 pp. January 1941.

PROCEEDINGS: VOLUME 86

Title page, table of contents, and index. Pp. i–ix, 593–626. July 22, 1940.

VOLUME 87

No. 3077. Further studies on the opalinid ciliate infusorians and their hosts, by Maynard M. Metcalf. Pp. 465–634, figs. 21–157. October 29, 1940.

VOLUME 88

No. 3090. Seven new species and one new genus of hydroids, mostly from the Atlantic Ocean, by C. McLean Fraser. Pp. 575–580, pls. 32, 33. September 13, 1940.

VOLUME 89

No. 3093. Two new anuran amphibians from Mexico, by Edward H. Taylor. Pp. 43–47, pls. 1–3. August 13, 1940.

No. 3094. The West American *Haliotis*, by Paul Bartsch. Pp. 49–58, pls. 6–8. August 15, 1940.

No. 3095. Revision of the scarabaeid beetles of the phyllophagan subgenus *Listrochelus* of the United States, with discussion of related subgenera, by Lawrence W. Saylor. Pp. 59–130, figs. 1–13. November 15, 1940.

No. 3096. The Cuban operculate land mollusks of the family Annulariidae, exclusive of the subfamily Chondropominae, by Carlos de la Torre and Paul Bartsch. Pp. 131–385, i–x, pls. 9–57. April 2, 1941.

No. 3097. Seven new crayfishes of the genus *Cambarus* from Florida, with notes on other species, by Horton H. Hobbs, Jr. Pp. 387–423, figs. 14–22. November 23, 1940.

No. 3098. Echinoderms from Greenland collected by Capt. Robert A. Bartlett, by Austin H. Clark. Pp. 425–433, pls. 58, 59. February 27, 1941.

No. 3099. A revision of the keyhole urchins (*Mellita*), by Hubert Lyman Clark. Pp. 435–444, pls. 60–62. December 12, 1940.

No. 3100. *Eurhoptodes*, a remarkable new genus of Philippine cryptorhynchine weevils, by Elwood C. Zimmerman. Pp. 445–448, fig. 23. November 1, 1940.

No. 3101. The polyclad flatworms of the Atlantic coast of the United States and Canada, by Libbie H. Hyman. Pp. 449–495, figs. 24–31. February 27, 1941.

No. 3102. New species of heterocerous moths in the United States National Museum, by William Schaus. Pp. 497–511. March 6, 1941.

No. 3103. *Dinotocrinus*, a new fossil inadunate crinoid genus, by Edwin Kirk. Pp. 513–517, pl. 63. February 28, 1941.

No. 3104. A supposed jellyfish from the pre-Cambrian of the Grand Canyon, by R. S. Bassler. Pp. 519–522, pl. 64. February 27, 1941.

No. 3105. Notes on birds of the Guatemalan highlands, by Alexander Wetmore. Pp. 523–581. March 26, 1941.

VOLUME 90

No. 3106. New fishes of the family Callionymidae, mostly Philippine, obtained by the United States Bureau of Fisheries Steamer *Albatross*, by Henry W. Fowler. Pp. 1–31, figs. 1–16. April 8, 1941.

No. 3108. Synopsis of the tachinid flies of the genus *Tachionmyia*, with descriptions of new species, by Ray T. Webber. Pp. 287–304, fig. 17. June 30, 1941.

No. 3111. The Chicora (Butler County, Pa.) meteorite, by F. W. Preston, E. P. Henderson, and James R. Randolph. Pp. 387–416, pls. 54–59, fig. 19. June 17, 1941.

No. 3114. A new genus of sea stars (*Plazaster*) from Japan, with a note of the genus *Parasterina*, by Walter K. Fisher. Pp. 447–456, pls. 66–70. June 18, 1941.

BULLETINS

No. 100, volume 13. The fishes of the groups Elasmobranchii, Holocephali, Isospondyli, and Ostariophysi obtained by the United States Bureau of Fisheries Steamer *Albatross* in 1907 to 1910, chiefly in the Philippine Islands and adjacent seas, by Henry W. Fowler. x + 879 pp., 30 figs. March 10, 1941.

No. 100, volume 14, part 1. Report on the Echinoidea collected by the United States Fisheries Steamer *Albatross* during the Philippine Expedition, 1907–1910. Part 2: The Echinothuridae, Saleniidae, Arbaciidae, Aspidodiadematidae, Micropygidae, Diadematidae, Pedinidae, Temnopleuridae, Toxopneustidae, and Echinometridae, by Theodor Mortensen. Pp. i-iv, 1–52, pl. 1, figs. 1–3. July 25, 1940.

No. 176. Life histories of North American cuckoos, goatsuckers, hummingbirds, and their allies, by Arthur Cleveland Bent. viii + 506 pp., 73 pls. July 20, 1940.

CONTRIBUTIONS FROM THF U. S. NATIONAL HERBARIUM: VOLUME 26

Title page, table of contents, and index. Pp. i–xii, 531–554. March 6, 1941.

PUBLICATIONS OF THE NATIONAL COLLECTION OF FINE ARTS

Catalog of American and European paintings in the Gellatly Collection, compiled by R. P. Tolman. 20 pp., 11 pls. 1940.

PUBLICATIONS OF THE FREER GALLERY OF ART

The Freer Gallery of Art of the Smithsonian Institution. 8 pp., 1 pl., 2 figs. 1940.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the Bureau has continued under the immediate direction of the editor, M. Helen Palmer. During the year the following Bulletins were issued:

Bulletin 126. Archeological remains in the Whitewater District, eastern Arizona. Part II. Artifacts and burials, by Frank H. H. Roberts, Jr. With appendix, Skeletal remains from the Whitewater District, eastern Arizona, by T. D. Stewart. xi+170 pp., 57 pls., 44 figs.

Bulletin 127. Linguistic material from the tribes of southern Texas and northeastern Mexico, by John R. Swanton. v+145 pp.

Bulletin 128. Anthropological Papers, Nos. 13–18. No. 13, The mining of gems and ornamental stones by American Indians, by Sydney H. Ball. No. 14, Iroquois suicide: A study in the stability of a culture pattern, by William N. Fenton. No. 15, Tonawanda Longhouse ceremonies: Ninety years after Lewis Henry Morgan, by William N. Fenton. No. 16, The Quichua-speaking Indians of the Province of Imbabura (Ecuador) and their anthropometric relations with the living populations of the Andean area, by John Gillin. No. 17, Art processes in birchbark of the River Desert Algonquin, a circumboreal trait, by Frank G. Speck. No. 18, Archeological reconnaissance of southern Utah, by Julian H. Steward. xii+368 pp., 52 pls., 77 figs.

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the Association to the Secretary of the Smithsonian Institution and are communicated by him to Congress, as provided by the act of incorporation of the Association.

During the year there was issued the Annual Report for 1936, volume 2 (Writings on American History). At the close of the year the following were in press: Report for 1936, volume 3 ("Instructions of the British foreign secretaries to their envoys in the United States, 1791–1812"); Report for 1937, volume 2 (Writings on American History, 1937–1938); Report for 1939, volume 1 (Proceedings); Report for 1940.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Forty-third Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with law, December 9, 1940.

ALLOTMENTS FOR PRINTING

The congressional allotments for the printing of the Smithsonian Annual Reports to Congress and the various publications of the Government bureaus under the administration of the Institution were

virtually used up at the close of the year. The appropriation for the coming year ending June 30, 1942, totals $88,500, allotted as follows:

Smithsonian Institution	$16,000
National Museum	43,000
Bureau of American Ethnology	17,480
National Collection of Fine Arts	500
International Exchanges	200
National Zoological Park	200
Astrophysical Observatory	500
American Historical Association	10,620
Total	88,500

Respectfully submitted.

W. P. TRUE, *Chief, Editorial Division.*

Dr. C. G. ABBOT,
Secretary, Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION

FOR THE YEAR ENDED JUNE 30, 1941

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds of the Smithsonian Institution, together with a statement of the appropriations by Congress for the Government bureaus in the administrative charge of the Institution.

SMITHSONIAN ENDOWMENT FUND

The original bequest of James Smithson was £104,960 8s. 6d.—$508,318.46. Refunds of money expended in prosecution of the claim, freights, insurance, etc., together with payment into the fund of the sum of £5,015, which had been withheld during the lifetime of Madame de la Batut, brought the fund to the amount of $550,000.

Since the original bequest the Institution has received gifts from various sources chiefly in the years prior to 1893, the income from which may be used for the general work of the Institution.

To these gifts has been added capital from savings on income, gain from sale of securities, etc., and they now stand on the books of the Institution as follows:

Avery, Robert S. and Lydia T., bequest fund	$51,445.64
Endowment fund, from gifts, income, etc	258,328.92
Habel, Dr. S., bequest fund	500.00
Hachenberg, George P. and Caroline, bequest fund	4,044.06
Hamilton, James, bequest fund	2,905.94
Henry, Caroline, bequest fund	1,216.20
Hodgkins, Thomas G., fund	146,392.62
Parent fund	728,867.62
Rhees, William Jones, bequest fund	1,065.72
Sanford, George H., memorial fund	1,995.18
Witherspoon, Thomas A., memorial fund	129,774.35
Special fund	1,400.00
Total endowment for general work of the Institution	1,327,936.25

The Institution holds also a number of endowment gifts, the income of each being restricted to specific use. These are invested and stand on the books of the Institution as follows:

Abbott, William L., fund, bequest to the Institution	$103,969.99
Arthur, James, fund, income for investigations and study of the sun and lecture on the sun	40,217.77
Bacon, Virginia Purdy, fund, for a traveling scholarship to investigate fauna of countries other than the United States	50,381.96

Baird, Lucy H., fund, for creating a memorial to Secretary Baird	$16,296.07
Barstow, Frederic D., fund, for purchase of animals for the Zoological Park	764.93
Canfield Collection fund, for increase and care of the Canfield collection of minerals	38,461.71
Casey, Thomas L., fund, for maintenance of the Casey collection and promotion of researches relating to Coleoptera	9,223.59
Chamberlain, Francis Lea, fund, for increase and promotion of Isaac Lea collection of gems and mollusks	28,318.52
Hillyer, Virgil, fund, for increase and care of Virgil Hillyer collection of lighting objects	6,609.11
Hitchcock, Dr. Albert S., Library fund, for care of Hitchcock Agrostological Library	1,375.68
Hodgkins fund, specific, for increase and diffusion of more exact knowledge in regard to nature and properties of atmospheric air	100,000.00
Hughes, Bruce, fund, to found Hughes alcove	18,248.71
Myer, Catherine Walden, fund, for purchase of first-class works of art for the use of, and benefit of, the National Gallery of Art	19,062.41
Pell, Cornelia Livingston, fund, for maintenance of Alfred Duane Pell collection	2,427.09
Poore, Lucy T. and George W., fund, for general use of the Institution when principal amounts to the sum of $250,000	81,367.65
Reid, Addison T., fund, for founding chair in biology in memory of Asher Tunis	30,134.19
Roebling fund, for care, improvement, and increase of Roebling collection of minerals	121,359.54
Rollins, Miriam and William, fund, for investigations in physics and chemistry	99,963.23
Smithsonian employees retirement fund	11,651.48
Springer, Frank, fund, for care, etc., of Springer collection and library	18,033.47
Walcott, Charles D. and Mary Vaux, research fund, for development of geological and paleontological studies and publishing results thereof	11,635.83
Younger, Helen Walcott, fund, held in trust	50,112.50
Zerbee, Frances Brinckle, fund, for endowment of aquaria	765.33
Special research fund, gift, in the form of real estate	20,946.00
Total endowment for specific purposes other than Freer endowment	881,326.76

The above funds amount to a total of $2,209,263.01, and are carried in the following investment accounts of the Institution:

U. S. Treasury deposit account, drawing 6 percent interest	$1,000,000.00
Consolidated investment fund (income in table below)	1,093,301.51
Miscellaneous special funds	115,961.50
	2,209,263.01

CONSOLIDATED FUND

Statement of principal and income for the last 10 years

Fiscal year	Capital	Income	Percentage	Fiscal year	Capital	Income	Percentage
1932	$712,156.86	$26,142.21	3.67	1937	$738,858.54	$33,819.43	4.57
1933	764,077.67	28,185.11	3.68	1938	867,528.50	34,679.64	4.00
1934	754,570.84	26,650.32	3.66	1939	902,801.27	30,710.53	3.40
1935	706,765.68	26,808.86	3.79	1940	1,081,249.25	38,673.29	3.47
1936	723,795 46	26,836.61	3.71	1941	1,093,301.51	41,167.38	3.76

FREER GALLERY OF ART FUND

Early in 1906, by deed of gift, Charles L. Freer, of Detroit, gave to the Institution his collection of Chinese and other Oriental objects of art, as well as paintings, etchings, and other works of art by Whistler, Thayer, Dewing, and other artists. Later he also gave funds for the construction of a building to house the collection, and finally in his will, probated November 6, 1919, he provided stock and securities to the estimated value of $1,958,591.42 as an endowment fund for the operation of the gallery. From the above date to the present time these funds have been increased by stock dividends, savings of income, etc., to a total of $6,030,586.91. In view of the importance and special nature of the gift and the requirements of the testator in respect to it, all Freer funds are kept separate from the other funds of the Institution, and the accounting in respect to them is stated separately.

The invested funds of the Freer bequest are classified as follows:

Court and grounds fund	$675,573.37
Court and grounds maintenance fund	169,656.83
Curator fund	687,507.68
Residuary legacy	4,497,849.03
Total	6,030,586.91

SUMMARY

Invested endowment for general purposes	$1,327,936.25
Invested endowment for specific purposes other than Freer endowment	881,326.76
Total invested endowment other than Freer endowment	2,209,263.01
Freer invested endowment for specific purposes	6,030,586.91
Total invested endowment for all purposes	8,239,849.92

CLASSIFICATION OF INVESTMENTS

Deposited in the U. S. Treasury at 6 percent per annum, as authorized in the United States Revised Statutes, sec. 5591	$1,000,000.00

Investments other than Freer endowment (cost or market value at date acquired):		
Bonds (30 different groups)	$467,455.26	
Stocks (41 different groups)	663,791.62	
Real estate and first-mortgage notes	71,249.00	
Uninvested capital	6,767.13	
		$1,209,263.01
Total investments other than Freer endowment		2,209,263.01
Investments of Freer endowment (cost or market value at date acquired):		
Bonds (48 different groups)	$2,433,088.10	
Stocks (57 different groups)	3,584,772.34	
Real estate first-mortgage notes	9,000.00	
Uninvested capital	3,726.47	
		6,030,586.91
Total investments		8,239,849.92

CASH BALANCES, RECEIPTS, AND DISBURSEMENTS DURING THE FISCAL YEAR [1]

Cash balance on hand June 30, 1940		$391,308.66
Receipts:		
Cash income from various sources for general work of the Institution	$90,769.51	
Cash gifts and contributions expendable for special scientific objects (not to be invested)	43,063.26	
Cash gifts for special scientific work (to be invested)	20,713.17	
Cash income from endowments for specific use other than Freer endowment and from miscellaneous sources (including refund of temporary advances)	59,800.43	
Cash received as royalties from Smithsonian Scientific Series	23,404.41	
Cash capital from sale, call of securities, etc. (to be reinvested)	157,121.07	
Total receipts other than Freer endowment		394,871.85
Cash income from Freer endowment	233,079.22	
Cash capital from sale, call of securities, etc. (to be reinvested)	1,059,332.29	
Total receipts from Freer endowment		1,292,411.51
Total		2,078,592.02

[1] This statement does not include Government appropriations under the administrative charge of the Institution.

Disbursements:		
From funds for general work of the Institution:		
Buildings—care, repairs, and alterations	$2,852.33	
Furniture and fixtures	182.43	
General administration [1]	34,184.52	
Library	2,129.85	
Publications (comprising preparation, printing, and distribution)	20,378.94	
Researches and explorations	23,720.74	
		$83,448.81
From funds for specific use, other than Freer Endowment:		
Investments made from gifts, from gain from sale, etc., of securities and from savings on income	26,774.50	
Other expenditures, consisting largely of research work, travel, increase, and care of special collections, etc., from income of endowment funds, and from cash gifts for specific use (including temporary advances)	90,339.94	
Reinvestment of cash capital from sale, call of securities, etc	154,138.09	
Cost of handling securities, fee of investment counsel, and accrued interest on bonds purchased	2,090.48	
		273,343.01
From Freer Endowment:		
Operating expenses of the gallery, salaries, field expenses, etc	43,399.19	
Purchase of art objects	96,719.64	
Investments made from gain from sale, etc., of securities	15,976.19	
Reinvestment of cash capital from sale, call of securities, etc	1,047,577.09	
Cost of handling securities, fee of investment counsel, and accrued interest on bonds purchased	20,986.95	
		1,224,659.06
Cash balance June 30, 1941		497,141.14
Total		2,078,592.02

[1] This includes salary of the Secretary and certain others.

Included in the foregoing are expenditures for researches in pure science, publications, explorations, care, increase, and study of collections, etc., as follows:

Expenditures from general funds of the Institution:		
Publications	$20,378.94	
Researches and explorations	23,720.74	
		44,099.68

Expenditures from funds devoted to specific purposes:		
Researches and explorations	$60,879.90	
Care, increase, and study of special collections	4,836.80	
Publications	5,470.90	
		$71,187.60
Total		115,287.28

The practice of depositing on time in local trust companies and banks such revenues as may be spared temporarily has been continued during the past year, and interest on these deposits has amounted to $715.42.

The Institution gratefully acknowledges gifts or bequests from the following:

Mrs. W. W. Daly, for Smithsonian endowment fund.

Friends of Dr. Albert S. Hitchcock, for the Hitchcock Agrostological Library.

Cornelia L. Pell, for the Pell Collection.

Research Corporation, further contributions for research in radiation.

John A. Roebling, further contributions for research in radiation.

H. Nelson Slater, for investigations in connection with early cotton machinery.

Julia D. Strong, for National Collection of Fine Arts.

Mrs. Mary Vaux Walcott, for purchase of certain specimens.

All payments are made by check, signed by the Secretary of the Institution on the Treasurer of the United States, and all revenues are deposited to the credit of the same account. In many instances deposits are placed in bank for convenience of collection and later are withdrawn in round amounts and deposited in the Treasury.

The foregoing report relates only to the private funds of the Institution.

The following annual appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1941:

General expenses	$386,260.00
(This combines under one heading the appropriations heretofore made for Salaries and Expenses, International Exchanges, American Ethnology, Astrophysical Observatory, and National Collection of Fine Arts of the Smithsonian Institution and for Maintenance and Operation of the United States National Museum.)	
Preservation of collections	627,470.00
Printing and binding	73,000.00
National Zoological Park	239,910.00
Cooperation with the American Republics (transfer to the Smithsonian Institution)	28,500.00
Total	1,355,140.00

The report of the audit of the Smithsonian private funds is printed below:

SEPTEMBER 8, 1941.

EXECUTIVE COMMITTEE, BOARD OF REGENTS,
Smithsonian Institution, Washington, D. C.

SIRS: Pursuant to agreement we have audited the accounts of the Smithsonian Institution for the fiscal year ended June 30, 1941, and certify the balance of cash on hand, including Petty Cash Fund, June 30, 1941, to be $499,041.14.

We have verified the record of receipts and disbursements maintained by the Institution and the agreement of the book balances with the bank balances.

We have examined all the securitites in the custody of the Institution and in the custody of the banks and found them to agree with the book records.

We have compared the stated income of such securities with the receipts of record and found them in agreement therewith.

We have examined all vouchers covering disbursements for account of the Institution during the fiscal year ended June 30, 1941, together with the authority therefor, and have compared them with the Institution's record of expenditures and found them to agree.

We have examined and verified the accounts of the Institution with each trust fund.

We found the books of account and records well and accurately kept and the securities conveniently filed and securely cared for.

All information requested by your auditors was promptly and courteously furnished.

We certify the Balance Sheet, in our opinion, correctly presents the financial condition of the Institution as at June 30, 1941.

Respectfully submitted,

WILLIAM L. YAEGER,
Certified Public Accountant.

Respectfully submitted.

FREDERIC A. DELANO,
VANNEVAR BUSH,
Executive Committee.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1941

ADVERTISEMENT

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1941.

WHAT LIES BETWEEN THE STARS[1]

By Walter S. Adams

Carnegie Institution of Washington, Mount Wilson Observatory, Pasadena, Calif.

[With 4 plates]

We are accustomed to think of the material upon which the astronomer works as consisting mainly of the sun and its planetary system, occasional comets, and the vast array of stars and nebulae which dot our skies at night. In other words the astronomer is largely concerned with matter in a sufficiently condensed form either to radiate light like the hot sun and stars or to reflect light like the cool planets and satellites. In recent years, however, new information has obliged us to consider more seriously what lies between the stars, and it is this subject which I should like to discuss briefly with you this evening.

In the first place it is interesting to realize how much space there really is in our stellar universe and how little of it is actually occupied by the stars. If this room represented an average portion of space and we let a floating speck of dust represent a star, we could not allow another speck within the room to represent another star because no matter where we put it the two would be too near each other. The star nearest to the sun is about 25 million million miles away. Another way of realizing how much of space is comparatively empty is through its average density. If we put together everything we can observe directly, such as the stars and nebulae, in the general neighborhood of our sun, and divide the total by the volume of the space in which it lies, we find for each cubic inch 1 grain of matter divided by 1 followed by 22 ciphers. At the center of our galaxy the density is probably 10 times greater. These values may perhaps be in error by a factor of 10 but we need not feel the deep concern of the individual who thought the lecturer gave 1 billion instead of 10 billion years for the possible life of our sun and was enormously relieved when he discovered his error.

[1] Alexander F. Morrison Lecture. Reprinted by permission from Publications of the Astronomical Society of the Pacific, vol. 53, No. 312, April 1941.

If, at the turn of the century, a layman or even an astronomer had been asked what lies in the vast spaces between the stars he would probably have answered, "Little or nothing." There might be an occasional wandering mass of cold rock like an asteroid or a meteorite or specks of dust such as produce our "shooting stars" when they strike the earth's atmosphere; but in general, space was considered as essentially empty, with practically all the material in our galaxy condensed into the stars.

About 1900 several observations raised serious questions regarding the supposed emptiness of space. The most important of these were Barnard's photographs of the Milky Way which showed great lanes and holelike structures in the huge clouds of stars which compose this shining ring of light. To interpret these as real vacancies where no stars exist was the natural impulse, but gradually observations accumulated which made it impossible to retain this view. The "holes" were too sharply bounded and in many cases were associated with visible cloudlike luminosity which veiled the region. Moreover the presence of numerous long "tunnels" among the stars pointing toward the earth seemed altogether improbable. The final evidence was afforded by the photographs made at the Lick Observatory of the outer universes of stars, the extragalactic nebulae, many of which showed definite streaks of absorbing material crossing the main body of the nebula. The apparent vacancies were due to the presence of dark clouds of cosmic dust which absorb and scatter the light from the stars behind, either obliterating them completely or leaving them comparatively faint and inconspicuous.

These cosmic clouds are composed of very finely divided particles of dust and are often of enormous extent, especially in the region of the Milky Way. When their thickness is great they blot out the stars behind them, and when thin they redden the starlight passing through them just as dust or smoke in the earth's atmosphere reddens sunlight, especially near sunrise or sunset when the path through the dust is long. The importance of these cosmic clouds in astronomy is very great: they affect the brightness and color of every star whose light passes through them, and calculations of the distances of remote stars, the size of our universe, and the quantity of matter within it are all profoundly influenced by the absorption and scattering of light in interstellar space.

I shall not dwell longer on this most interesting question of dust clouds in space since many of you heard Dr. Seares give a lecture on this subject a few months ago on the occasion of the award to him of the Bruce Medal of the Astronomical Society of the Pacific. To those of you who may not have heard him I can recommend a reading of his admirable presentation of the whole subject in the

Publications of the Society.[2] Modern observations with blue and red color filters show the remarkable degree to which the presence of such obscuring clouds modifies the appearance of great areas of the sky, especially in the region of the southern Milky Way, and illustrate the use made by astronomers of the power of red light to penetrate cosmic dust.

We now know at least three forms of solid matter in interstellar space. There are probably dark stars, that is, stars with temperatures so low that they give out little or no visible light. If we knew where to look we might be able to detect some of them with sensitive heat-measuring devices—which will measure the heat given out by a candle at a distance of many miles—but as it is we can only infer their existence. We know that in the descending scale of stellar temperature we find cooler and cooler stars until finally we observe objects which give out only a faint red light. It seems reasonable to assume that there may be many others with still lower temperatures which have become invisible and are gradually approaching the condition of cold bodies like our planets or asteroids. They are probably small stars which have gone through the successive temperature stages of stellar development at a rather rapid rate.

In addition to these occasional dark stars there are in the spaces between the visible stars great numbers of smaller masses of matter, "chunks" as Dr. Hubble has called them, such as now and then fall upon the earth in the form of meteorites. They are cold bodies with the chill of the depths of space upon them, commonly ranging in mass from a few pounds to a few tons.

Finally and most important, we have the dust of space, often gathered into huge cosmic clouds which weaken or even blot out the stars behind them and give us much of the variegated pattern of the Milky Way.

There is, however, another form in which we find matter existing in space, matter not in the solid state but in the form of gas, consisting of molecules, atoms, and even portions of atoms, the tiny electrons of the physicist. Much of our knowledge of this subject is of very recent date, and because it is new and because it is certain to affect our views of the conditions in interstellar space I should like to discuss it in a simple way this evening.

This brings us at once to a consideration of a few elementary facts about the spectrum, for it is from the spectrum that we gain essentially all our knowledge of matter in the gaseous state. As you all know, white light is a mixture of several primary colors and the eye combines them into an impression which we call white. The

[2] Publ. Astron. Soc. Pacific, vol. 52, p. 80, 1940.

spectrum is simply a map of the colors spread out into a band beginning with violet at one end and passing through blue, green, and yellow into red at the other. It can be produced in several different ways, the simplest of which is by a triangular piece of glass called a prism. When white light passes through a prism the violet part of the light is bent a certain amount when it comes out, the green a little less, and the red still less. The final result is a continuous band of color extending from violet to red. You have all seen flashes of such a spectrum when sunlight falls upon a cut-glass bowl or the edge of a beveled mirror.

Now the important fact is that any chemical element, when heated to the point where it vaporizes and gives out light, gives it in a pattern of colored bright lines which is unique for each element and defines it absolutely. Some patterns are comparatively simple, while others are exceedingly complex. For example, sodium has relatively few lines in its spectrum and nearly all the light which sodium vapor emits is concentrated in two strong lines of orange color. These are so dominant that they define the color of a sodium lamp completely, as you all know who have ridden through the yellow glare of the street lights now in such common use. Similarly neon gas has its strongest lines in the red portion of the spectrum and hence neon signs are red to the eye, while mercury light with an exceedingly strong green line in its spectrum is predominantly green in color. On the other hand the vapor of iron produced in an electric arc has an extraordinarily rich spectrum consisting of some 2,000 lines distributed throughout all the colors of the spectrum. In the absence of predominant lines of one color, luminous iron gas appears nearly white to the eye.

One other fact should be remembered before we pass to our immediate astronomical applications of the spectrum. A hot, solid body or one consisting of dense gases gives out a spectrum which is a continuous band of color, not one of bright lines. When the light from such a body, a star for example, passes through a gas of somewhat lower temperature the gas will absorb light of just the color of its characteristic lines, and we shall have a pattern of absorption or dark lines. For example, when the light from the filament of an ordinary incandescent lamp is passed through a slightly cooler tube of sodium vapor we see the two strong yellow lines of sodium as dark lines on the yellow background of light given by the filament.

In astronomy we have almost a precise analogy to the filament and tube of sodium vapor. The body of the sun or of a star corresponds to the filament and gives out a continuous band of color, while the gaseous atmosphere corresponds to the sodium tube and produces the absorption lines. The principal difference is that the atmosphere of

a star like our sun contains not only sodium but a great variety of other elements and so we get not only sodium lines but an immense number of other lines as well—such as those of hydrogen, calcium, iron, and some 60 other elements.

It is hardly necessary to say that the spectra of the elements, these characteristic patterns of bright lines which define them uniquely and individually, have been studied with extraordinary care by physicists and astronomers alike for many years. Maps have been made, the intensities of the lines measured, and their positions determined with an almost uncanny degree of precision. As a result astronomers know almost every element which enters into the composition of the sun and even the most distant stars, merely through comparison of the positions and intensities of the dark lines produced in their atmospheres with the well-recognized bright lines of terrestrial elements.

One other point should be considered. When we observe a star, its light comes to us through the earth's atmosphere which is itself composed of various gases. These gases are cold and because they are cold remain in the form of molecules. Intense heat will break up molecules into atoms, and in the atmospheres of the hotter stars we find only the lines due to atoms. Molecules, however, can also emit and absorb light and give spectrum lines arranged in characteristic patterns, the principal difference from those produced by atoms being that molecules usually give an enormous number of closely packed lines arranged in the form of bands. As a result when we observe the spectrum of a star we find superposed upon it the bands of gases such as oxygen, water vapor, and carbon dioxide in the atmosphere of the earth. These bands lie mainly in the red and infared portion of the spectrum.

About 40 years ago two very narrow sharp lines were observed in the violet part of the spectrum of a star in the constellation of Orion. They were at once identified with well-known lines of calcium, but their positions did not vary periodically as did those of the lines from the star, and it was clear that they were not of stellar origin. They were called provisionally "stationary" lines, and Sir Arthur Eddington suggested the bold hypothesis that they originated in the absorption of the atoms of calcium gas in interstellar space. Some 20 years later two more such lines were discovered at the Lick Observatory in the yellow portion of the spectrum. These are due to sodium and are the characteristic lines to which we have already referred. In 1936, observations with a spectroscope on the 100-inch telescope at Mount Wilson led to the discovery of several additional lines, a few of which were identified as due to titanium and potassium. By this time the interstellar origin of all such lines had been fully established,

and through the work of Struve, of the Yerkes Observatory, the intensities of the calcium lines were being used as a measure of the distances of the stars in which they were observed. The greater the distance of the star, the greater the amount of interstellar gas through which its light passes, and the stronger the lines. Several broad hazy lines, apparently originating from interstellar gases but differing greatly in appearance from the normal sharp lines, had also been discovered by Merrill at Mount Wilson.

Until recent months, accordingly, the situation was that the gases of calcium, sodium, titanium, and potassium had been identified in interstellar space but that the origin of several fairly conspicuous lines still remained unknown. The identified lines all arise from the atoms of the elements, and naturally astronomers searched for identifications of the remaining lines in the atomic spectra of other elements. This led to no success, however. The possibility was then considered whether the unidentified lines could arise from molecules instead of atoms. As I have already said, under ordinary conditions, molecules of compounds produce bands consisting of hundreds or even thousands of closely packed lines as contrasted with the simpler spectrum of relatively few lines arising from the atom. Under the conditions of interstellar space, however, with extraordinarily low densities and temperatures, the molecular spectrum might well be simplified and even reduced to a few observable lines. The suggestion that the broad diffuse lines observed by Merrill might have a molecular origin was put forward by several investigators, and in the specific case of one of the sharp lines discovered at Mount Wilson a tentative identification with a line of the common hydrocarbon gas CH was offered by Swings and Rosenfeld. An identification resting upon a single line, however, necessarily remained somewhat doubtful.

The next step was taken by McKellar at the Dominion Astrophysical Observatory. Applying to molecular spectra the principles derived from a study of some of the identified atomic lines, he was able to predict the positions of several additional lines for each molecular spectrum. Thus if the single relatively prominent line tentatively assigned to CH were correctly identified, there should be at least three other fainter lines present in another region of the spectrum. Similarly McKellar could predict the positions of certain lines of the familiar cyanogen gas CN.

Hence the final solution of the question came back to the observer. Since the predicted lines were faint and narrow, it was clear that photographic plates of high contrast and fine grain must be used and that exposure times would be long. Fortunately a bright star was available, Zeta Ophiuchi, lying near the southern Milky Way. The 100-inch telescope and a spectroscope 114 inches long were used with

exposure times of about 4 hours. The results were conslusive. The predicted lines of hydrocarbon gas CH all appeared in their correct positions with their calculated intensities. In the case of cyanogen gas CN, the evidence is based upon fewer lines but is equally strong. Hence the existence of the gases CH and CN in interstellar space may be regarded as practically certain.

After this brief description of how these discoveries were made, a few comments upon the meaning of the results may be of interest. In the first place, we have learned that several of the common elements exist in space in the form of atoms; sodium, calcium, potassium, and titanium have been identified, and it is very probable that many if not all of the others could be recognized if only conditions were favorable for the appearance of their spectra. Then we have very recently found that two common gases, or at least two slightly modified common gases, are present, cyanogen and hydrocarbon gas. This is the first discovery of molecules in interstellar space. That hydrogen, the most abundant element of all in the universe, has not been discovered directly is due to the fact that the lines which it could show under the conditions present in space are in an inaccessible part of the spectrum, and, like the lines of many other important elements, are cut off by the ozone in the earth's atmosphere, which in the words of Russell "lies like a black pall upon the dreams of the astrophysicist." However, we do find hydrogen combined with carbon in hydrocarbon gas and thus have ample evidence for its presence.

Although the lines of hydrocarbon gas are well marked and at least one of them is fairly conspicuous, it is the enormous length of the path of light from the stars rather than the density of the gas which provides enough absorbing molecules. The actual density is extraordinarily low. In a cubic mile of space there are probably only a very few thousand molecules; and when we remember that the diameter of a molecule is less than one ten-millionth of an inch it is easy to see that very little of the space is occupied. But if the path is long enough, a good many molecules will be encountered by the light from a distant star, and observable absorption lines will result. The same reasoning holds true for lines originating from atoms such as sodium and calcium. Dunham estimates that there is one sodium atom in about 25 cubic yards of space, and yet in the spectra of very distant stars the interstellar sodium lines are conspicuous.

A calculation by Russell of the average density of interstellar gas in general gives a value of about 2 preceded by 24 ciphers of the density of water. So great are the distances, however, that in the volume of space whose radius is equal to that of the nearest fixed star, the mass of the interstellar gas amounts to about one-fourth

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the mass of the sun. So if we consider the huge dimensions of our galaxy, the amount of matter contributed by interstellar gases is by no means negligible.

An interesting and somewhat amusing subject is that of the temperature of these gases in space. We are accustomed to dwell upon the intense cold of outer space far removed from the heat of any nearby star and we are quite right in doing so. A thermometer placed in interstellar space would show a temperature of about 3° above absolute zero on the Centigrade scale or about 455° below zero on the usual Fahrenheit scale. But this is by no means the temperature of the atoms or molecules of a highly diffuse gas. In such a gas the effect of the radiation of a star which falls upon an atom is to drive out electrons, or, to use a technical word, to ionize it. It is the same process which happens when light falls upon a photoelectric cell: electrons are driven out and the energy of these electrons when amplified rings a burglar alarm or opens a garage door. The electrons in space have a temperature depending upon the mean energy with which they are driven out of the atom, and when they collide with the atom they raise its temperature. Thus the atoms and molecules of gas are lifted to a high temperature estimated at some 10,000° to 20,000° on the Fahrenheit scale. The interesting feature about the process, as Eddington has shown, is that it depends upon the quality and not the quantity of the radiation, so that the temperature of a gas far in space will be just as high as if it were near a star. The rate of production of electrons will be slower but the temperature will not be affected. So we may say that we have two kinds of temperature in space, one of space itself as registered by a thermometer, and a very different one for the gases, which through their remarkable structure are able to build up and maintain a temperature of thousands of degrees in spite of the bitter cold of the medium which surrounds them.

There is one other interesting characteristic of the molecules and atoms in our interstellar gases. Under ordinary conditions such as in a physical laboratory they are in a wild state of excitement, flying about rapidly, colliding with one another and knocking off and picking up electrons in a fraction of a millionth of a second. In the extremely rarefied conditions of gas in space, however, the situation is quite different. Collisions are extremely rare and the atoms and molecules can remain for weeks and perhaps even months in the least excited state which the state of their being will allow them to have. To use a homely comparison, if we touch a sleeping cat the cat responds with a a twitch of an ear or a leg which represents the least possible disturbance to its equilibrium. So the lazy molecules of space when disturbed by a ray of light or heat from a star seek to

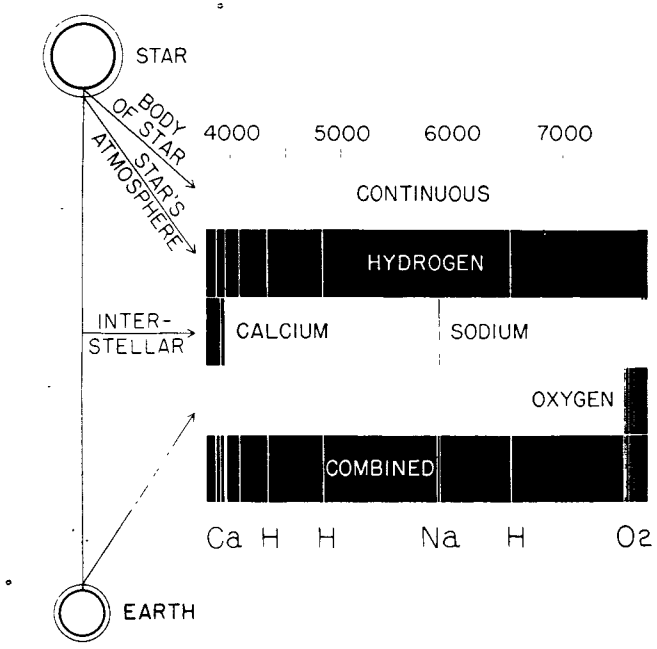
move as little as possible from their condition of rest and the spectrum lines which we observe are those due to transitions of this sort. This is the reason why the complicated spectrum of a gas like cyanogen, consisting of hundreds of closely packed lines, is reduced to a meager three or four lines when observed in interstellar space. These are the only lines which the molecule in its lowest state of energy can absorb.

In this brief outline we have discussed the gaseous material of space, how it is studied, and what we know about its composition, temperature, and density. We have seen that three of the most important elements which enter into the composition of the universe, hydrogen, nitrogen, and carbon, are present in the form of compounds, and that others as yet unidentified are represented by spectral lines in the interstellar gases. If in most of our considerations we have had our ciphers on the left-hand side of the significant figures instead of the right, it is because we have been dealing with atoms and molecules instead of stars and universes. Even so, such is the volume of space that the mass of the dust and gas which lies between the stars may well exceed by several fold all the matter actually visible with our greatest telescopes.

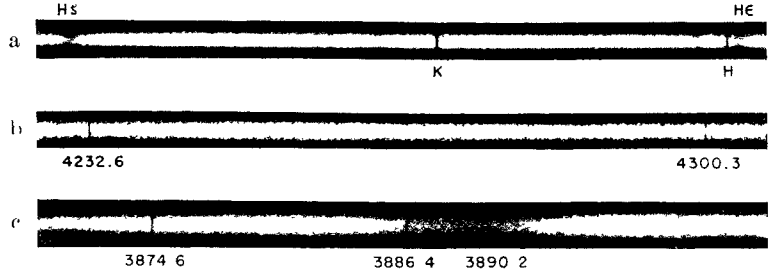


FIELD OF NGC 6553.

Photographed by Baade in blue and in red light. The exposure times were so chosen that an unobscured field of normal color would have appeared similar on the two photographs. Clouds of cosmic dust between us and the stars scatter and absorb the blue light much more than the red.

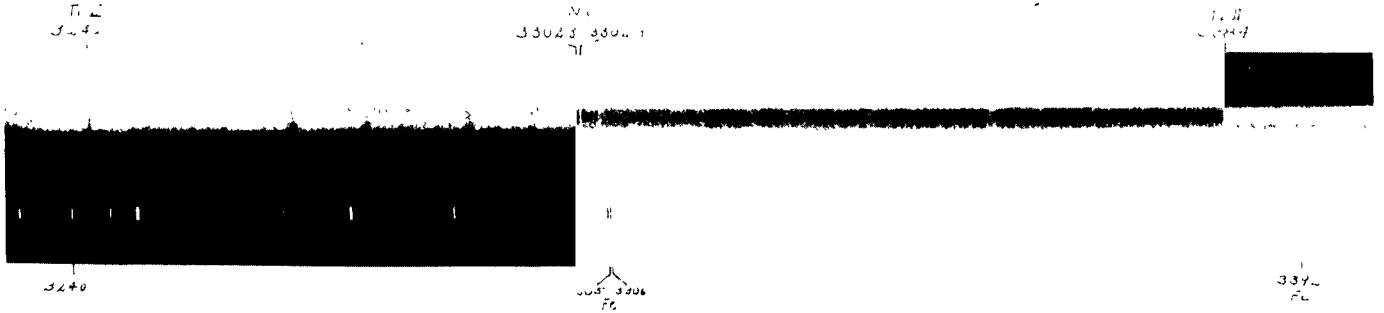


1 DIAGRAM SHOWING THE ORIGIN OF THE CONTINUOUS SPECTRUM AND VARIOUS TYPES OF ABSORPTION LINES IN STELLAR SPECTRA

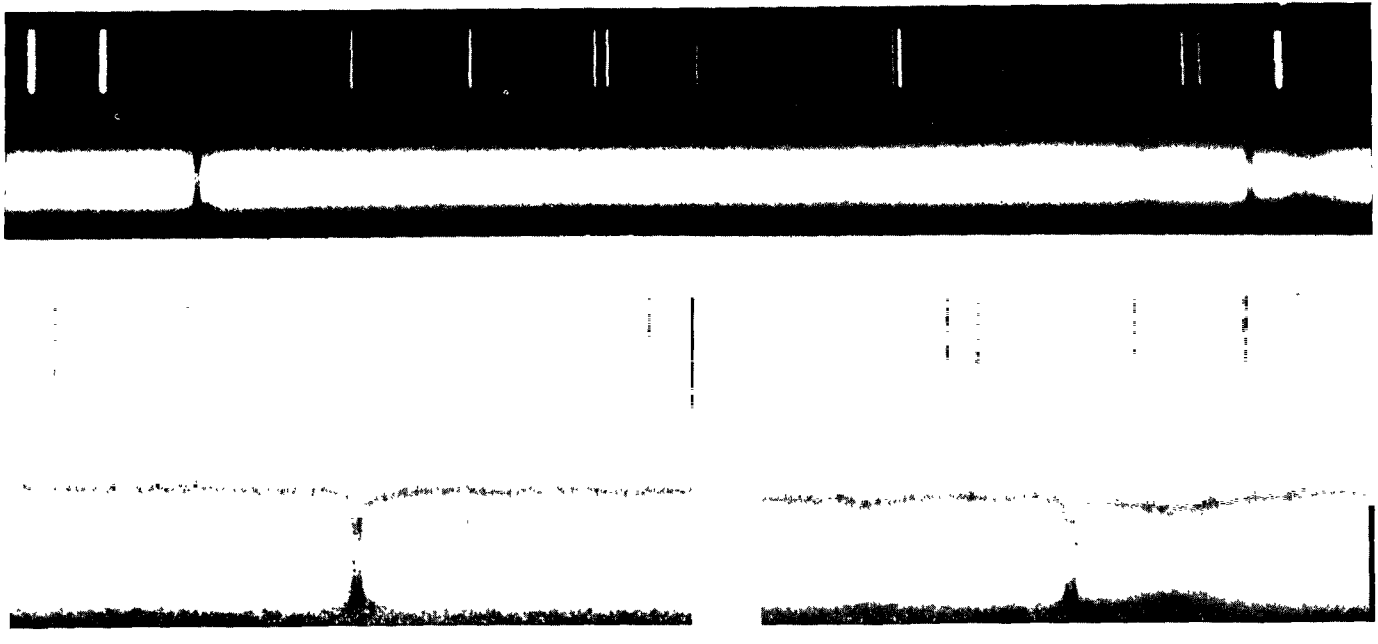


2 STELLAR SPECTRA SHOWING ABSORPTION LINES DUE TO INTERSTELLAR GASES.

a, 55 Cygni. H and K lines due to interstellar ionized calcium, and diffuse lines due to stellar elements.
b, ζ Ophiuchi. Interstellar lines λ 4232, unidentified, and λ 4300, hydrocarbon gas (CH).
c, 20 Ophiuchi. Interstellar lines of CH, λ 3886 and λ 3890, also λ 3874.6 and a trace of λ 3874.0, both cyanogen (CN).



PORTION OF ULTRAVIOLET SPECTRUM OF χ^2 ORIONIS, SHOWING INTERSTELLAR LINES DUE TO NEUTRAL SODIUM (λ 3302) AND IONIZED TITANIUM (λλ 3242, 3384).



DOUBLE INTERSTELLAR LINES OF IONIZED CALCIUM (H AND K) IN SPECTRUM OF χ AURIGAE

The components are probably due to separate clouds of calcium gas moving with slightly different velocities.

ARTIFICIAL CONVERTERS OF SOLAR ENERGY[1]

By H. C. HOTTEL
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A study of the literature on solar energy utilization has convinced me of the existence of an unalterable tradition among speakers and writers on the subject. One must always begin such a discussion by expressing the earth's reception of solar energy in units no one has thought before to use, the more startling the better. In keeping with this tradition, I shall mention a few old figures and add my own. The earth and its atmosphere intercept the equivalent in energy of 21 billion tons of coal per hour; 6 million tons per second; the equivalent in 3 minutes of the annual American energy consumption of about 1 billion tons; energy at a rate sufficient each year to melt a layer of ice 114 feet thick; on an acre at noon the equivalent of the discharge of a healthy stream from a garden hose spouting fuel oil instead of water.

Having made the conventional beginning, let me add what many of you know: that figures such as these are almost irrelevant to the problem of practical utilization of solar energy. They have attracted uncounted crank inventors who have approached the problem with little more mental equipment than a rosy optimism. Now, an informed pessimism is sometimes the healthiest mood in which to approach an engineering problem; and I want to use a little space in an endeavor to put you in that mood. Consider a solar power plant utilizing 1 acre of land, and operating on the principle of conversion of solar energy to heat in steam used to run an engine. There is incident at noon, normal to the sun's rays and outside the earth's atmosphere, 7,400 horsepower of solar energy. On a clear day, of this quantity about 5,000 horsepower arrives at the earth. Allowing for the efficiency of collection of the sunlight as heat in the working fluid to be used in the engine, the quantity drops to about 3,300 horsepower. Utilizing the highest achieved efficiency of conversion of solar heat to useful power (results of Dr. Abbot's experiments), the

[1] Presented before the symposium on Solar Energy, Harvard Chapter, Spring, 1940. Reprinted by permission from Sigma Xi Quarterly, vol. 29, No. 1, April 1941.

horsepower output drops to 490. These calculations have so far all been on the assumption of normal incidence of the sun on the collector systems. To achieve this the collector must be mounted to turn with the sun and must be far enough from its neighbor not to shade the latter in morning or afternoon. Introducing a ground-coverage factor of one-third to allow for this, the output is cut to 163 horsepower. But this figure applies only to the hours when the sun shines with full intensity. Converting to a 24-hour basis of operation on clear days in summer in Arizona, the output drops to 83; or in winter to 46 horsepower; or for the year to 68 horsepower. Passing on to the average year of New York weather, the output is down to 30 horsepower. Even if one stops at a reasonably attainable value of 50 horsepower in Arizona, that figure is one one-hundred-and-fiftieth of the original 7,400 horsepower.

For rough orientation as to the meaning of these figures, suppose the possibility of a 50-horsepower steady output from an acre in Arizona be accepted. To evaluate this power, let it be assumed that electric power can be produced in a large modern steam plant at a cost of 0.6 cents per kw.-hr., or $53 a kilowatt year, making the output of our 1 acre worth $1,900 per year. In the absence of knowledge of labor costs, maintenance, etc., one can only guess the capital value of such an output. Capitalization at 15 percent is almost certainly overoptimistic, and even that yields but $13,000 to spend on the entire plant, or about $2.60 per square yard. Since the ground coverage is but one-third, $8 are available to build each square yard of reflectors, mounts, and accessories. The result is one so often encountered in engineering projects: indecisive. It may be possible to build a plant for such an amount; much more exact knowledge of performance and costs is necessary than was at hand in making the above rough estimate. What I have particularly wanted to emphasize by this preliminary consideration is perfectly obvious to the engineer, namely, that solar power is not there just for the taking!

However, this preview has at least indicated that solar power is not completely outside the realm of economic feasibility. It is worthwhile, then, to examine in more detail the problem of use of solar energy by conversion to heat, a problem which has commanded the attention of engineers for three-quarters of a century.

First, a moment on some elementary principles of heat transmission. If a black metal plate is exposed to the sun, and cooling water is run under the plate fast enough to keep the plate from rising appreciably above the surrounding air temperature, substantially all the energy of the sun's rays intercepted by the plate shows up as energy in the water; the efficiency of collection of heat is nearly 100 percent, but the value of the heat is low because of its low tempera-

ture level. If the water enters 50° F. above the surrounding air temperature and flows through fast enough hardly to rise in temperature, there is the same interception and absorption of solar energy by the plate; but now much of it is used in keeping the plate up to temperature; it is lost to the surroundings by radiation and convection, and very little of the absorbed energy appears in the water stream. To improve the efficiency the losses must be cut down. There are several ways. The back side of the plate may be insulated, since it never sees the sun. Or a plate of glass may be placed over the metal plate and parallel to it, with an inch or so of air space between. Then the plate receives and absorbs almost as much sunlight as before—the glass transmits about 90 percent—but the losses from the metal to the outer atmosphere are reduced: the convection loss because of the imposed stagnation of the air, and the radiation loss because glass, though transparent to the sun's rays, is opaque to the long-wave infrared radiation emitted by the hot metal plate. Variations of this idea include the use of several glass plates and of glass vacuum chambers. Another method of cutting down losses is to reduce the area at which losses occur relative to the area of the interceptor of the energy to be collected. This may be done by choosing the most favorable orientation of the plate, that is, normal to the sun's rays, or by use of a concentrating device, such as a mirror, which intercepts rays covering a large area and brings them to a focus on an object of much smaller area where the heat loss is consequently correspondingly small despite the high temperature.

From this discussion there emerges a threefold basis of classification of solar energy collectors: (1) By nature of orientation of the collector (whether and how completely it follows the sun), (2) by amount of concentration achieved by mirrors, (3) by amount and type of insulation of the receiver surface. It is perfectly obvious that many of the early inventors and engineers in this field were familiar with these principles in a general way.

One might now ask, "With all this work, have not the possibilities of energy production by conversion to heat been so thoroughly studied as to yield a definite answer?" Unfortunately, no. Qualitative familiarity with the principles involved, these men had certainly; but with the exception of the work of Dr. Abbot, their experiments and records indicate inadequate quantitative knowledge of the problem. As an exemple, consider the simplest possible collector, the flat plate insulated with several air-spaced glass layers. Willsie's work at Needles in 1909 indicated the possibilities of this simplest of solar plants, but it left unanswered the question of merit relative to the much more efficient—and more expensive—plant of Abbot, and did not yield data permitting the design of such a plant for any given

climate. Among the projects at M. I. T. made possible by Dr. Godfrey Cabot's endowment for research on utilization of solar energy is one having as its first objective the determination of the performance characteristics of solar energy collectors of different types, the performance, of course, being correlated with records of incident solar energy so as to permit calculations of expected performance in any locality where sunlight records are available. The first and so far the only type of collector studied has been the flat plate, which will now be considered briefly.

Since each additional layer of glass and air cuts down the losses from such a plate, it is apparent that with glass having perfect transmission one could build a collector which, without any focusing or concentrating device, would still collect efficiently at a very high temperature level. But the best glass is not perfect. It doesn't absorb much solar energy when one picks the right glass—and there is ample evidence that early experimenters were too casual in their choice of glass in that respect—but there is a reflection loss of about 4 percent at each surface. Consequently, as glass plates are added the point is ultimately reached where the reduction in heat loss from the metal plate is more than offset by the reduction in intensity of incident radiation due to reflection losses. The optimum number of plates to use will be less the more intense the sunlight, more the colder the weather and the higher the temperature of collection of heat.

The controlling part played by reflection losses in the design of flat-plate collectors having been brought out, the desirability of a low reflecting glass was discussed with Professor Hardy, of our Physics Department. The result was the invention by Drs. Turner and Cartwright of a method of processing glass to give it a permanent surface of reflectivity approaching zero at one point in the spectrum. The process has already demonstrated its importance in a great many uses ranging from spectacle lenses through bomb sights to high-speed cameras and the solar-corona camera which was described in the first article of this series. Here is an excellent example of a need in one field stimulating research, the results of which have many applications in other fields. The special glass has not yet been used for an experimental solar-energy collector, but calculations indicate that its use should make possible the attainment of temperatures up to 800° F. without any mirrors or lenses or so-called concentrating devices.

Another problem of flat-plate collectors is that of optimum tilt. Obviously they are too cheap a type of collector system to warrant being mounted to follow the sun, but they may profitably be tilted permanently toward the Equator. A little consideration will indicate that the optimum tilt depends very definitely on the use to

which the collected heat is to be put. If the objective is the maximum collection during the entire year, tilting should favor the summer season. If, on the other hand, the objective is to supply heat for a load which varies throughout the year, the tilt should be chosen to favor that part of the year in which the load is highest.

As to the use of such collectors, it has already been indicated that one must find first just what they can do. But speculation is permissible. One might visualize a large artificial lake with sloped sides formed by throwing up an earthen ring around a surface-scraped center, the bottom and sloping sides being surfaced with asphalt. Floating on this lake, which is, say, 20 to 40 feet deep, is an enormous raft covering it completely. On the raft is a layer of insulation, then a system of flat-plate collectors. Forced circulation of lake water through the collectors whenever they attain a temperature above the reservoir will produce a large body of hot water available for continuous operation of a power plant. The working fluid in the engine might be low-pressure steam or, to cut down engine size, a fluid which boils at lower temperatures. It is not possible to state at this time whether such an idea has possibilities.

Another less ambitious use of flat-plate collectors might be that of house heating in relatively cold but sunny climates, or summer air conditioning. Some preliminary figures may indicate the prospects in this direction. Consider house heating in New England, and take as a basis the furnishing of one therm of heat throughout the heating season—100,000 B. t. u.: the heat obtained by burning 1 gallon of fuel oil with normal efficiency of combustion. If 1 square foot of flat-plate receiver covered with three plates of glass and tilted 40° southward is operated in connection with 1½ cubic feet of water in a well-insulated tank, and the water is pumped from the tank to the receiver and back whenever the receiver is hotter than the tank, the combination will supply all but 15 percent of the 100,000 B. t. u. required during the season; the 15 percent has to be supplied as auxiliary heat in December, January, and February. The value of the heat saved is the cost of 0.85 gallons of fuel oil, or about 6 cents. Capitalizing this at 6 percent gives only $1 available to be spent on the roof collector and tank. This is plainly not enough, but the answer is interesting because we have not determined the optimum number of glass plates, or tilt, or ratio of roof to tank area, or considered the possibility of some day having treated glass of lower reflectivity. More particularly, the idea looks interesting for localities where the ratio of winter to summer sunshine is somewhat more favorable than in Boston, and the winter heating requirements somewhat lower. According to a recent publication of Dr. Abbot's, Dr. F. G. Cottrell has proposed a somewhat similar storage system in which sand is to be used instead of water. Whether the ad-

vantages of low-cost installation and ability to store heat at a higher temperature would be offset by the disadvantage of lower efficiency of collection is a point requiring study.

Whether the use of flat-plate collectors together with a storage system is economically possible for house heating or air conditioning in certain areas of the earth, whether other types of collector will prove cheaper for these uses or for power generation, whether power generation from solar heat demands the development of a new heat-engine cycle, and whether power generation by any process dependent on direct conversion of sunlight into heat with consequent unavoidable losses due to the degradation of energy is sound—these are questions which it is hoped this program will help to answer. Regardless of the result, the present considerable and increasing importance of solar heat for hot water in certain parts of this country indicates the need for a comprehensive study of the factors involved in the design of collectors.

Now to come to a second project, related to the one just discussed. Conventional heat-power plants are characterized by a cost of power production depending enormously on the capacity of the plant; and we have seen that solar power does not now look very attractive when compared to large-scale operation of steam plants. If, on the other hand, it were possible to operate small solar plants with an efficiency comparable to large ones, the comparison with fuel-fired plants might lead to some very different conclusions. So far as the collectors of the sunlight are concerned there is little indication that the cost should be other than proportional to the amount of collector area. If then it were possible to devise an engine with moderate efficiency even in small units, one might have something worthwhile. The second project is, in effect, a study of a type of engine which may have just such desired characteristics. When two dissimilar conducting materials are joined to form a loop and the two junctions are kept at different temperatures, heat flows into the loop at the hot junction, a portion of its energy is converted to electrical energy and the rest flows out of the cold junction as heat. The phenomenon involved here has itself long been known; many investigators have been led to speculate upon it as a possibility for large-scale thermoelectric power production, but then to dismiss it as unimportant because the effect is small. Of the early experiments in this field, the best yielded an over-all efficiency of conversion of energy from gas to electricity of only 0.6 percent. Consequently, until recently, the sole use of the phenomenon has been in the measurement of temperature.

In trying to better these results, one naturally asks, first, the question "What property must a metal or alloy have besides high thermoelectric power if it is to be of interest for heat-power generation?"

Plainly, the material should have a low thermal conductivity to minimize the loss of heat flowing from the hot to the cold junction. Moreover, the electrical conductivity should be as high as possible in order not to dissipate an excessive amount of electrical energy as heat within the "engine." The ratio of the two quantities, thermal conductivity to electrical conductivity, is known as the Wiedemann-Franz ratio; and it has just been shown that this ratio should be as low as possible. A correlation of data from the literature and a consideration of theoretical limitations indicate a sort of conspiracy on the part of Nature to prevent the finding of any material with a Wiedemann-Franz ratio less than a certain minimum value. A study of the properties of zinc-antimony alloys indicates that the thermoelectric power is a maximum for an alloy containing 36 percent zinc, but that, owing to the extremely abnormal value of the Wiedemann-Franz ratio in this alloy, there is an advantage in use of an alloy containing 43 percent zinc, since the thermoelectric power of such an alloy is almost as good as the best, and the Wiedemann-Franz ratio is very much more favorable.

An "engine" consisting of an alloy of zinc and antimony containing 43 percent zinc against the alloy copel has been found to produce a 5 percent useful conversion of heat to electrical power in the external circuit, when the temperature difference of the hot and cold junctions of the system is maintained at 400° C. To the layman this may not sound very imposing, but it is to be remembered that 25-percent efficiency is attained only in the best of modern steam power plants and that 5 percent would not be considered bad for a small engine. Moreover, it is to be remembered that a great many alloys and compounds exist, the thermoelectric properties of which are unknown, that it is not inconceivable that further study of the problem may produce a material increase in efficiency in this kind of an engine. With such an idea in mind, there has been initiated at M. I. T. a program of study of the thermoelectric properties of various compounds and alloys. The work is in too early a stage to justify consideration at the present time.

So far in this discussion only the so-called heat engine has been considered as a means of conversion of solar enregy to useful power. The term, to an engineer, means a device which receives energy as heat at a certain temperature, converts part of that energy to useful power and throws away the rest to a so-called heat sink at a second lower temperature. That this discussion was concerned in the first instance with the use of steam in the engine and in the second instance with the use of a thermocouple for conversion to power is immaterial; in each case the first step has been the conversion of solar energy to heat. Now, there is available to the scientist and engineer a powerful tool, known as the second law of thermodynam-

ics, that permits him to appraise the possibilities of the heat engine; and it tells him, for example, that the enormous reservoir of heat which the earth's atmosphere constitutes is not available for use in a heat engine. This same second law of thermodynamics states that, in the act of collecting sunlight and converting it to heat at a lower temperature level, a degradation of solar energy has occurred; the energy has been made less available for conversion to power even though none of it has been lost; and no process—no matter how clever the inventor—can restore the energy to a form as intrinsically useful as when it arrived here as solar energy just before its conversion to heat.

In consequence of this important limitation on what can be expected so long as one's interest is restricted to heat engines, it is appropriate to consider other means of conversion of solar energy to power which do not involve as a first step the collection of the energy as heat, but which instead make use of the special nature of the energy as it arrives. Solar energy reaching the earth consists of a jumbled mass of radiations of wave lengths varying from the short ultraviolet through the visible spectrum and out into the infrared, roughly one-third of the total energy lying in the visible spectrum. The radiation might be likened, if the analogy is not pushed too far, to a shower of bullets—unit quantities of energy, known as quanta, each of a particular wave length. The quanta of shortest wave lengths have the greatest unit energy content; and almost two-thirds of the total energy consists of relatively impotent quanta in the infrared. If, instead of pouring all these quanta into the funnel of a heat engine, they are given a chance to show their individuality, what are their specialties? One, of particular interest to us at present, is the phenomenon of photoelectricity, the ability of light quanta of certain wave lengths to knock electrons out of atoms or atomic lattices in crystals and produce an electric current.

Many of you have encountered this phenomenon in using that type of camera exposure meter which indicates on a dial the intensity of illumination. Light is there being converted into electrical energy which is in turn used to make the galvanometer needle move. The light-sensitive unit of such a device is one of two kinds, each referred to as a blocking-layer photocell. The copper oxide cell is typical; it consists of a massive plate of copper which has been oxidized on one face and then etched, to produce thereby a layer grading from cuprous oxide through all proportions of oxygen down to pure copper. The cuprous oxide surface is covered with a thin film of another metal, so thin as to be transparent to light quanta. There is thus produced a sandwich in which the outer layers are metal and the inside layers consist of material graded in character in a direction normal to the surface. If a quantum of visible light strikes

the thin metal cover of the cuprous oxide, it passes through that and through the cuprous oxide layer, penetrating to some point in the structure where the composition lies between that of cuprous oxide and copper (the so-called blocking layer); and there the quantum—the bullet of energy—succeeds in knocking out an electron from the crystal lattice. The electron, being liberated in territory where the view depends on which way it looks, finds, in general, that the going is easier when it migrates toward the copper rather than through the cuprous oxide to the other metal film. This preferential movement of the electrons in one direction constitutes an electric current.

How important is this phenomenon for power generation from sunlight? Tests on copper oxide photocells indicate that of the visible light quanta falling on such a cell only about 5 percent succeed in causing an electron to show up in the external electric circuit, that, furthermore, the voltage efficiency of the system is only about 10 percent, with a consequent over-all efficiency of conversion of luminous energy to power of one-half of 1 percent. Preliminary calculations indicate that a tenfold increase in this efficiency would make copper oxide cells interesting for solar power production; and there is no present reason to believe such an accomplishment impossible. It is not easy, however, for the physicist doesn't really know just what goes on in the blocking layer of the photocell. Clearly the problem is one which demands a fundamental study completely divorced from any present considerations of a practical nature. Such a project has been initiated in our Electrical Engineering Department in connection with a broad program of study of insulators and semiconductors—the cuprous oxide of our photocell is such—from the atomphysical viewpoint. The problem is really one of studying the laws of motion of electrons in semiconductors; the effect of crystal versus amorphous structure; of crystal structures in which there is strong ionic binding, such as sodium chloride versus crystal structures in which the bonding is atomic, as in sulfur; the effect of temperature on conduction and break-down in insulators; the effect of an excess of one of the components of a crystalline compound present in the crystal. When the nature of the migration of electrons in semiconductors is better understood, when their interaction with the lattice structure is able to be formulated quantitatively, then one can attack with some hope of success the difficult barrier-layer photocell problem. Whether such an attack succeeds or not, the knowledge acquired in the course of the problem is certain to be of enormous value in a field of great practical importance, insulation research.

I come now to the last of the M. I. T. solar-energy projects, one which like the previous one depends on the special properties of sunlight rather than its over-all energy content. Dr. Thimann

pointed out in his contribution [2] our complete dependence on the process known as photosynthesis: the use by green plants of solar energy in the visible spectrum to produce carbohydrates out of carbon doxide and water. He also emphasized the extreme complexity of the process—the fact that no one has been able to extract the essential chlorophyll and carotenoids from a plant leaf and make the reaction go in a test tube. By some process, which we have hardly begun to understand, the leaf structure succeeds in capturing the energy of sunlight and transferring it to the reaction: carbon dioxide+water=carbohydrate+oxygen, a reaction absorbing 112 kilocalories per gram atom of carbon. But to store solar energy chemically one does not have to carry out the same reaction that nature does; any chemical reaction which absorbs energy and produces a fuellike product capable of later combustion to return the energy for use at the proper time would be acceptable. Chemical industry has often succeeded in competing with nature in the production of a material of desired characteristics, not by attempting a complete imitation of nature, but by focusing attention on those properties of the natural material important to its use and imitating them with a synthetic product, perhaps chemically quite different from nature's product.

In the photochemical field, then, a combination of sensitizers and catalysts might be attempted that would allow us to perform some relatively simple energy-storing reaction such as the decomposition of water. A major problem would be to provide suitable intermediate steps in the process in order that the relatively small energy quanta, which constitute visible light, could be used in stepwise fashion such as nature apparently uses them in the photosynthetic apparatus of green plants. The photochemical system would probably have one of the characteristics of the photochemical system of the plant, namly heterogeneity. But the heterogeneity might be accomplished not by constructing some sort of imitation leaf, but rather, for example, by a colloidal solution.

Another approach to the problem is possible. We may renounce the production of metastable products or mixtures with a high content of chemical energy—fuels or explosives—and turn our attention to the utilization of the energy of the unstable intermediate products obtained in almost every photochemical reaction. Among the ways of utilizing these products is to convert their high energy content into electrical energy. A reaction must be found in which passage from the unstable to the stable state can be made to proceed as an electrode reaction in a galvanic cell. Examples of this kind are oxidation-reduction reactions in electrolytes. The properties of such a reaction, carried out in what is known as a photogalvanic cell, are

[2] Thimann, Kenneth V., The action of light on organisms. Sigma Xi Quart., vol. 29, No. 1, pp. 23–35, April 1941.

being studied at the Institute. The system chosen consists of an organic dye, thionine, and ferrous iron in the form, for example, of a ferrous sulfate solution. The two components form in the solution a reversible oxidation-reduction system.

$$(\text{dyestuff}) + Fe^{++} \rightleftarrows \underset{\substack{\uparrow \\ \text{(colorless)}}}{\text{leukodyestuff}} + Fe^{+++}$$

Ferric iron is a much stronger oxidizing agent than thionine; therefore, in the dark, all the thionine is in the form of the dye, and all the iron in the ferrous form. If, however, the mixture is illuminated by the light absorbed by thionine—i. e., visible light in the region 5000–7000 A. (green, yellow, red light)—the thionine molecules are activated by light and become capable of oxidizing ferrous iron. Since the reduced thionine is colorless, the reaction is recognized by a decoloration of the solution. This bleaching proceeds to a steady state, whose exact character depends on the intensity of illumination. In this state, the velocity of the photochemical bleaching reaction is exactly compensated by that of the back-reaction restoring the equilibrium. As soon as the light is switched off, the system reverts to its original state.

Experiments have been conducted on the kinetics of this interesting photochemical process, using a photometric method for the determination of the concentration of the dye under different conditions. Of more interest in the present connection is the electrochemical effect of light in the thionine-iron system. As the composition of the solution changes through illumination, its electrode potential is also changed; if two platinum electrodes are placed in the solution and the electrolyte surrounding one of them is illuminated while the other is kept dark, a potential difference is established between the two electrodes and a current flows from the dark to the illuminated electrode. The problem of the photogalvanic effect demonstrated by this experiment has two elements: the first and simpler question is that of the electromotive force produced by a given illumination; the second is that of the current that can be drawn from such a photogalvanic cell.

So far, experiments have been concerned with the first part of the problem. The photogalvanic potential of the thionine-iron system has been measured in relation to the concentrations of all the components and the light intensity. A pronounced maximum of potential is found at a certain concentration of the dyestuff, and a strong increase in effect with decreasing acidity of the solution. From such experiments, it has been possible to develop a quantitative picture of the photogalvanic effect in satisfactory agreement with the experimental results. The next step is a study of the factors affecting cur-

rent withdrawal from such a device, a phase of the program which has just commenced.

As to whether photogalvanic cells of this or similar types have practical importance as solar energy converters it is too early to hazard an opinion. Certainly their study has the merit of presenting problems in photochemistry which, while complex, are not so complex as to defy analytical treatment. In that respect they satisfy the condition which the scientist has learned to impose on himself, namely, not to ask questions of Nature which are so difficult that he cannot yet begin to understand her answer.

In summary, I have tried to point out that the best-known method of utilizing solar energy by artificial means is the relatively simple one of first converting the energy to heat; that, today, engineering data are inadequate properly to determine the value of such heat, whether for conventional use as heat or for conversion to power; that, if heat is converted to power, we are limited in possible efficiency by the second law of thermodynamics; that consequently it is necessary to turn to the fields of photochemistry and photoelectricity where theoretical limitations on expected output are less severe; that in turning to these fields it is found that the problems which arise are of so complicated a nature as to point plainly to the need for a long-range program of research into fundamental phenomena, research divorced almost completely for the time being from any considerations of a practical nature. To summarize this summary, with respect to the future of solar energy utilization, your guess is as good as mine.

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THE NEW FRONTIERS IN THE ATOM[1]

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[With 9 plates]

The anniversary celebration of a great university is indeed an important occasion, and it is appropriate to signalize the event by a symposium on "The University and the Future of America," for a a great institution of learning is eternally youthful, and youth looks always to the future. I am greatly honored to be included in this distinguished gathering, and it gives me especial pleasure to join in wishing our sister institution many happy returns.

In a discussion bearing on the future, the scientist is always in something of a dilemma. On the one hand, he is cautioned to make only very limited prognostications, for he has learned the very limited region of applicability of existing knowledge and the likelihood of error in speculation. On the other hand, he faces the future with eager excitement and curiosity about what is beyond the present frontiers of knowledge, and he is naturally tempted to speculate and indeed to indulge in day dreams. Perhaps I may convey something of what is in the minds of physicists these days by a brief discussion of some recent developments of the current intensive attack on the new frontier in the atomic world—the nucleus of the atom.

ATOMS

The atomic constitution of matter has long been a keystone of natural science. At the beginning of this century it was a keystone in a structure having as pillars the principles of the conservation of energy and the indestructibility of matter. In the nineties, it was almost axiomatic to say that the building blocks of nature are the atoms—indivisible, indestructible entities, permanent for all time. But the discovery of radioactivity altered all this. There followed

[1] An address delivered at the symposium on "The University and the Future of America," on the occasion of the Fiftieth Anniversary Celebration of Stanford University, June 16–19, 1941. Reprinted by permission from volume entitled "The University and the Future of America," published by Stanford University Press.

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the discovery of the electron and the proton as smaller and more fundamental constituents of matter and the atom itself became the happy hunting ground of the experimental physicist. Atomic physics developed rapidly; for the atom was found to be a domain of almost incredible richness, and today, thanks perhaps to the newspapers, our children speak knowingly of smashing atoms!

To explain the wonderful phenomenon of radioactivity, Rutherford came forward in 1904 with a revolutionary hypothesis which reduced the complicated and mysterious observations of radioactivity to simple order. According to Rutherford, not all of the atoms have existed for ages and will exist for all time, but there are some atoms in nature that are energetically unstable and in the course of time, of their own accord, blow up with explosive violence. These are the natural radioactive substances, and the fragments given off in the atomic explosions are the observed penetrating rays.

It was not long before Rutherford's hypothesis was established as a law of nature and formed a greater keystone, replacing the chemists' conception of the atom and serving as a foundation for a new science, the science of the atomic nucleus.

Time does not permit an adequate historical résumé of the development of nuclear physics, but for the present purpose it is sufficient to say that the ideas of Rutherford and Bohr on the structure of atoms are now firmly established. There is an abundance of evidence that an atom consists of a nebulous cloud of planetary electrons whirling about a very dense sun, the positively charged nucleus, and that it is in the nucleus that the atomic explosions of radioactivity occur. Indeed, our assurance that this is so rivals our confidence that the planets revolve about the sun!

ATOMIC NUCLEUS

Let us now proceed immediately to a consideration of the structure of the nucleus. The nucleus consists of a closely packed group of protons and neutrons, elementary building blocks of nature some 2,000 times heavier than the electrons. The neutrons are electrically neutral while the protons carry positive charges, and for each proton in the nucleus there is a corresponding negative electron outside, for the atom as a whole is uncharged. Since the number of electrons outside determines the ordinary chemical and physical properties of the atom, it follows that the nuclear charge determines the place of the atom in the periodic table of the elements.

Thus, the nucleus is the body and soul of the atom. More than 99.9 percent of the atom's mass is in the nucleus and the nuclear charge determines the nature of the atom, its chemical and physical properties.

TRANSMUTATION OF THE ELEMENTS

These considerations reduce the age-old problem of alchemy to simple terms. For we see to change one element into another is simply to change the nuclear charge, i. e., the number of protons, in the nucleus. The subject of transmutation of the elements has recently received a great deal of attention in the laboratory. All sorts of transmutations have been produced on a minute scale—helium has been made from lithium, magnesium from sodium, and even mercury has been turned into gold. The day may come when we will indeed possess the philosopher's stone and will be able to transmute the elements on a grand scale. But interesting as these developments are, I should like to draw your attention to two other subjects, artificial radioactivity and the question of tapping the vast reservoir of energy in the nucleus of the atom.

ARTIFICIAL RADIOACTIVITY

One of the early results of atomic bombardment was the discovery that neutrons could be knocked in or knocked out of the nucleus to produce radioactive isotopes of the ordinary elements. Thus, for example, the nucleus of the ordinary sodium atom contains 11 neutrons and 12 protons, 23 particles in all, and so it is called sodium 23 (or Na^{23}); and by bombardment it was found that a neutron could either be added to make sodium 24 or subtracted to make sodium 22, both isotopic forms not occurring in the natural state. The reason that these synthetic forms are not found in nature is that they are energetically unstable. They are radioactive and in the course of time blow up with explosive violence. Sodium 24 has a half-life of 14.5 hours, i. e., it has an even chance of disintegrating in that time, turning into magnesium by the emission of an electron. Sodium 22, on the other hand, has a half-life of 3 years and emits positive electrons to turn to stable neon 22.

These artificial radioactive isotopes of the elements are indistinguishable from their ordinary stable relatives until the instant they manifest their radioactivity. This fact deserves emphasis, and it may be illustrated further by the case of chlorine. Chlorine consists of a mixture of two isotopes, 76 percent of Cl^{35} and 24 percent of Cl^{37}, resulting in a chemical atomic weight of 35.46 which is the average weight of the mixture. By elaborate technique, to be sure, it is possible to take advantage of the extremely slight difference in chemical properties and bring about separation of these isotopes, but in ordinary chemical, physical, and biological processes, the chlorine isotopes are indistinguishable and inseparable. The artificial radioactive isotopes Cl^{34} and Cl^{38} are likewise indistinguishable. In fact,

Cl^{34} is more nearly identical in properties to the natural isotope Cl^{35} than is the other natural isotope Cl^{37}. And again I would say that the radioactive characteristic of Cl^{34} becomes evident only at the moment it blows up to turn into the neighbor element sulfur.

RADIOACTIVE TRACER ATOMS

In these radioactive transformations of the artificial radioactive isotopes, the radiations given off are so energetic that the radiations from individual atoms can be detected with rugged and reliable instruments, called Geiger counters. Thus, radioactive isotopes can be admixed with ordinary chemicals to serve as tracer elements in complicated chemical or biological processes.

As an illustration of the power of this new technique of labeling and tracing atoms, let us consider iodine in relation to the thyroid gland. It is well known that the thyroid takes up and stores iodine, and this fact can be demonstrated strikingly by feeding an individual iodine including a small quantity of radioactive iodine. Before the feeding, the radioactivity of the food can be measured by placing it near a Geiger counter, thereby giving a measure of the iodine content. Later the progress of the iodine through the body can be observed by placing the Geiger counter next to various parts of the body. Likewise, the proportion of the fed iodine in the various body fluids at any time can be determined quickly by taking small samples of the fluids and measuring their radioactivity. After some hours it is found that a large part of the iodine taken in has collected in the thyroid, a fact that is readily established by placing a Geiger counter next to the gland (pl. 1, fig. 1) and observing the activity while finding no appreciable activity elsewhere. This technique makes it possible to study the behavoir of the thyroid in health and in disease, and much interesting work along this line has been carried out recently.

RADIO-AUTOGRAPHY

Although the tracer elements are readily detected with the Geiger counter, there is a photographic method which for many purposes has obvious advantages. This method is sometimes called radio-autography and is illustrated by plate 1, figure 2. Here a minute amount of radioactive phosphorus in the form of sodium phosphate was added to the nutrient solution of a tomato plant, and after a day or so leaves were placed against a photographic film enclosed in a light tight paper envelope. The penetrating rays from the radioactive phosphorus produced the developed contact image shown in the figure, which gives an accurate and detailed picture of the uptake of phosphate by the plant. Now, indeed, the same method works

very well also for the thyroid, as is shown in plate 2, which is a photomicrograph of a thin section of thyroid tissue containing radio-iodine; alongside is the radio-autograph obtained from the same microsection by placing it against a photographic plate. The distribution of the iodine in various parts of the gland is shown in surprising detail.

Similarly striking radio-autographs of the distribution of phosphorus and strontium in rats are shown in plate 3, figure 1. Here two rats were fed radiophosphorus and radiostrontium respectively, and then some hours or days later they were sacrificed, and frozen sections of the entire bodies of the animals were placed against a photographic plate. The resulting radio-autographs show clearly that both strontium and phosphorus are selectively deposited in the bones, phosphorus being more widely distributed in other tissue. The distribution of the strontium in the bones also appears to be quite different from that of phosphorus as radio-autographs of the sections of bones clearly show (pl. 3, fig. 2).

These examples serve to illustrate the power of the new technique of radioactive tracer atoms. It has often been said that the progress of science is the progress of new tools and new techniques, and I think we may look forward to accelerated developments in biology resulting from the tracer elements.

ARTIFICIAL RADIOACTIVE SUBSTANCES IN THERAPY

It is somewhat afield for me to discuss medical problems, but I should like to direct your atention to the possibilities of the artificial radioactive substances in the treatment of cancer and allied diseases. It is well known that at the present time there are two main approaches to the treatment of neoplastic disease, surgery and radiation. It is sometimes possible to cut out a cancer completely and effect a cure, and in other circumstances, it is possible to destroy a tumor by irradiation with X-rays or radium. The mechanism whereby the radiation destroys the tumor without destroying an excessive amount of surrounding normal tissue is doubtless extremely complicated, but in any case it is evidently important to localize the radiation to the tumor as much as possible. Perhaps the idea would be approached if a means were at hand to irradiate each and every malignant cell without irradiating a single normal cell.

The artificial radioactive substances open for the first time the possibility of an approach to such selective irradiation of tissue. The above examples of tracers suggest the treatment of thyroid tumors with radioactive iodine, bone tumors with radioactive strontium and radioactive phosphorus. These possibilities are being investigated as is the more specific problem of finding a radioactive

substance that is selectively taken up by tumor tissue. If there were time, I should like to describe work along this line in progress in several laboratories, and especially to speak of the important progress that is being made in the treatment of leukemia, but I must content myself with only mentioning these new developments in medicine, which are so promising for the future.

ATOMIC ENERGY

For a long time astronomers have been vexed with a problem, the problem of the source of stellar energy, for there is evidence that the sun has been blazing at its present brilliance for thousands of millions of years, and no ordinary fuel could be responsible for such an eternal fire.

The discovery of radium posed to the physicist a similar difficulty; for it was found that radium gives off every hour enough energy to heat its own weight of water to boiling, and this it continues to do for more than a thousand years. Such a vast source of energy in the radium atom was as difficult to understand as the evidently limitless store of heat in the sun. The problem was of fundamental interest and all sorts of possibilities were considered even to the abandonment of the principle of the conservation of energy.

But the first clue to the solution of the problem appeared in 1905 when Einstein announced the theory of relativity. One of the revolutionary consequences of the theory was that matter is a form of energy and that presumably in nature processes go on in which matter is destroyed and transformed into more familiar forms of energy such as heat, radiation, and mechanical motion. The relativity theory gave as the conversion factor relating mass to equivalent energy, the square of the velocity of light—a very large number, even to an astronomer! Thus, the theory indicated that, if a glass of water were completely destroyed, more than a billion kilowatt hours of energy would be released, enough to supply a city with light and power for quite a time!

This exciting deduction was immediately accepted by the astronomers, who said, "Doubtless within the sun conditions are such that matter is being transformed to heat. Thus, slowly through the ages the sun is losing mass; its very substance is radiating into space."

Likewise, the physicists, who had other compelling reasons for accepting the Einstein theory, concluded that the source of the energy in the radium atom was a destruction of matter in the atomic explosion giving rise to the penetrating rays.

Although the fundamental assumptions on which the relativity theory was based were evidently sound, and the explanations of the source of energy of the sun and stars and radioactivity were

most attractive, until direct experimental verification was forthcoming, Einstein's great deduction could not be regarded as an established law of nature.

The first direct evidence of the truth of this fundamental principle was obtained in the first atom-smashing experiments a decade ago. It was observed that, when the nucleus of a lithium atom is hit by a proton having a kinetic energy of less than a million electron-volts, the result is the formation of two helium nuclei which fly apart with an energy of more than 17 million electron-volts; thus in the nuclear reaction in which hydrogen and lithium unite to form two helium atoms, there is a great release of kinetic energy.

Now one of the interesting and important occupations of the experimental physicist has been the measurement of the masses of atoms and the weights of atoms are known with great precision—much greater than any individual knows his own weight. In particular, it was known precisely that a lithium atom and a hydrogen atom have a total weight slightly greater than the weight of two helium atoms, and it was a great triumph for the Einstein theory when measurements showed that the excess kinetic energy with which the helium atoms flew apart in the hydrogen-lithium reaction corresponded exactly with the disappearance of mass according to the mass-energy relation. Literally hundreds of similar nuclear reactions have been studied in the intervening years, and in each instance the Einstein relation has been verified. At the present time this great principle has as firm an experimental foundation as any of our laws of nature.

URANIUM FISSION

Now that it is an experimental fact that matter can be converted into energy, it becomes of great practical importance to inquire whether the vast store of energy in the atom will be tapped for useful purposes. This question has recently taken on added interest through the discovery of a new type of nuclear reaction involving the heavy element uranium.

It has been known for some years that the heavy elements, such as lead, gold, and uranium, are relatively heavier than the middle-weight elements, such as copper and iron, or more precisely that the average weight of the neutrons, protons, and electrons in the heavy elements is greater than their average weight in the atoms near the middle of the periodic table. Accordingly it is to be expected that, if heavy atoms were split approximately in two forming corresponding middle-weight atoms, there would be a vast release of energy corresponding to the disappearance of matter in the transformation. Indeed, from known values of the masses, it can be calculated on the

basis of Einstein's mass-energy relation that each splitting or fission, as the process is called, of a uranium atom into two approximately equal parts releases an energy of about 200 million electron-volts, which is millions of times more heat per atom than is given off when ordinary fuel is burned. Thus, calculations show that 100 pounds of uranium would yield a billion kilowatt hours, which at 1 cent per kilowatt-hour would be 10 million dollars' worth of electrical energy.

For some time these considerations were largely academic because no way was known for producing fission of the heavy elements. But interest in the matter has now become extremely lively as a result of the discovery that fission of uranium is actually brought about by bombarding it with neutrons.

The phenomenon has, during the past 2 years, received intensive study in laboratories all over the world and several salient facts have emerged. First, the rare U^{235} isotope undergoes fission after absorption of a slow neutron. Second, the energy released in the fission process has been measured; and, as expected, it is found that, when a neutron having an energy less than an electron-volt enters the U^{235} nucleus, about 200 million electron-volts of energy is released. Third, it is found also that the fission process is so violent that usually the U^{235} nucleus does not break up into two parts only, but more often several neutrons are given off in addition to the two large fragments.

That neutrons are generated in the fission process is of the greatest interest because it opens up the possibility of a chain reaction, a series of nuclear reactions wherein the neutrons liberated in one fission process go to produce additional fissions in other atoms which in turn give rise to more neutrons which produce further fissions and so on. It is this possibility of a chain reaction that has excited the interest in uranium as a practical source of atomic energy.

Without going into further detail, it is perhaps sufficient to say that there is some evidence now that, if U^{235} could be separated in quantity from the natural mixture of the isotopes, a chain reaction could, indeed, be produced. But herein lies the catch, for there is no practical large-scale way in sight of separating the isotopes of the heavy elements, and certainly it is doubtful if a way will be found.

But I should not want to indicate that the uranium matter is a disappointment, that after all we shall never find a way to bring about fission of the heavy elements for useful purposes. Quite the contrary!

The present situation is not unlike the circumstances 50 years ago surrounding the then great question of whether man would ever be able to fly. In those days the fundamental laws of classical mecha-

nics were known, and they allowed the possibility of heavier-than-air flight. Moreover, there was an abundance of supporting observational evidence that flight should be possible; there were kites and there were the birds of the air. But man's realization of the dream awaited primarily the development of the combustion engine, a circumstance not so evidently connected with the fundamental problem of flight. Likewise the fundamental laws of nature recently revealed to us allow the possibility of obtaining useful nuclear energy, and radium and the sun and stars bear witness that this vast source of energy is being tapped in nature. Again success in this direction may await the development of a new intrument or technique just as the airplane depended on the gas engine.

Perhaps the problem awaits a deeper understanding of the forces that hold nuclei together. That there are little-understood forces operative in the nucleus is more than evident; especially from observations of the cosmic rays, it has been established that particles of matter called mesotrons of intermediate mass between electrons and protons play a dominant role in nuclear structure. Theoretical considerations suggest that the mesotrons may be connected with the primary forces in the nucleus, and accordingly, an understanding of mesotron forces may ultimately yield the solution of the practical problem of atomic energy.

THE GIANT CYCLOTRON

In order to study experimentally the mesotron problem, it is necessary to bombard nuclei with atomic projectiles having energies in the range of 100 million electron-volts rather than in the neighborhood of 10 million electron-volts at present available in cyclotron laboratories. To this end a giant cyclotron is now under construction on Charter Hill in Berkeley; some pictures of this great machine are shown in plates 8 and 9. Whether it will be the key to the vast store of energy in the atom, what new discoveries, what new insight into nature it will bring—only the future will tell!

THE PRINCIPLE OF THE CYCLOTRON

The principle of the cyclotron has been described as follows in a popular article by Henry Schacht.[2]

A circular chamber was placed between the poles of the magnet. Then all air was removed from the chamber and heavy hydrogen gas allowed to flow in. This so-called heavy hydrogen behaves in the same way as ordinary hydrogen. However, while the nuclei of ordinary hydrogen atoms contain one positively charged particle, or proton, heavy hydrogen nuclei contain two such particles

[2] Schacht, Henry, Lawrence's cyclotron, Part I and Part II. California Monthly for May and June, 1940.

plus one electron. Consequently, they weigh just twice as much as the nuclei of ordinary hydrogen atoms. They are known as deuterons.

The deuteron's added weight makes it an ideal atomic bullet. And here is how Dr. Lawrence planned to send streams of deuterons crashing into the nuclei of other atoms in a constant, destructive barrage: Inside the cyclotron chamber was a heated filament that emitted streams of electrons. These particles would collide with the electrons surrounding the nuclei of the hydrogen atoms and in the ensuing mix-up the nuclei and their satellites would become separated. The deuterons would be left free to float around the chamber. Eventually, the magnetic force set up by the cyclotron's magnet would pull them between two metal grids separated by a space across which an alternating electrical current of 10 or 15 thousand volts would be operating. As the deuterons floated into this space, they would receive a heavy shock, and under this stimulus fly off toward the side of the chamber. But the magnetic field would pull them back again in a semicircular path until they again came between the two grids. Again they would be shocked and be sent flying out toward the side. And again the magnet would pull them back to complete one full circle of the chamber and be shocked again.

At each jolt from the current the deuterons would gather more energy. This meant that they would go flying out from between the grids with constantly increasing force and in constantly widening circles. So you get the picture of the atomic bullets receiving shocks one right after the other from a weak electrical force. Each time the bullets receive a shock their energy is increased and they go on, describing wider and wider circles around the cyclotron chamber. Finally, they circle so widely that they reach a slit in the chamber wall and go flying out into the open air. The whole secret of the thing lies in making sure by means of the magnet that the atomic bullets are forced to come back for successive shocks until their energy is built up to the point where they can force their way to the exit. Dr. Lawrence figured that to bombard any substance with his atomic bullets, all he had to do was clamp this substance over the slit and let the onrushing stream of deuterons crash into it. This then was the theory put to the crucial test in 1934 at the Universiy Radiation Laboratory. Dr. Lawrence threw the switch that sent a high-powered radio transmitter pumping energy into the cyclotron and the first experiment with the 85-ton machine had begun.

Within a short time, physicists were amazed to hear that Lawrence and his cyclotron were not only changing familiar elements like platinum into other elements like iridium and gold, but were actually producing substances never before seen on earth. These were the artificially radioactive elements. Perhaps their character is best explained by illustration.

One of the experiments performed with the cyclotron involved the bombardment of iron atoms with the high-speed deuterons produced by the cyclotron. When the deuterons crashed into them with a force of about 8 million volts, the iron atoms were broken up. Some changed into atoms of cobalt or manganese. But others were converted into a new form of iron which, like radium, emitted streams of electrically charged particles. In other words, this new iron was radioactive. Thirty-four different elements were subjected to bombardment with the 85-ton cyclotron and all of them underwent a transformation, many turning into radioactive substances. Among the artificial radioactive materials produced by the cyclotron were sodium, phosphorus, iron, and iodine. It was even possible by bombarding bismuth to produce a degenerate form of radium called Radium E.

Another interesting product of these atomic bombardments was the neutron, a particle often found in the atomic nucleus. It adds to the weight of the nucleus but has no electrical charge, hence its name. When atoms were smashed by the bullets from the cyclotron, they flew into two parts. One might be an atom of a new radioactive element, and another an atom of a light element such as hydrogen or helium. But more often than either of these two, a neutron would appear. When the cyclotron was going full blast, 10 billion of these particles could be liberated every second.

It was found that radioactive elements, such as sodium and phosphorus, had certain advantages over radium which might make them extremely valuable for treatment of human disease. Preliminary experiments indicated that radioactive phosphorus might solve the problem of leukemia, the wasting blood disease for which no cure has yet been found. Radioactive sodium, iodine, phosphorus, and many other of the newly created elements proved to be priceless instruments in the hands of scientists interested in finding out more about our fundamental body processes. Finally, streams of released neutrons gave every indication of being a more powerful weapon against cancer than the X-ray. These discoveries marked the end of the first cycle of the cyclotron's career. So promising were the medical applications of its products that plans were laid to build a new 225-ton cyclotron. This machine was finished and housed in the William H. Crocker Radiation Laboratory on the University campus during the spring of 1939.

In its first performance the new atom smasher produced deuteron beams with a strength of 17 million volts, and "alpha rays," or beams of helium atoms, with an intensity of 34 million volts. These voltages were greater than any obtained with the original machine even though the electric current used to energize the particles within the cyclotron chamber was only 60 kilowatts. Such results were entirely unexpected, far exceeding anything Dr. Lawrence had hoped for on the first trial run.

On April 8, 1940, The Rockefeller Foundation of New York City announced its willingness, under certain conditions, to contribute $1,500,000 toward construction of a 4,900-ton cyclotron at the University. It would be 56 feet long, 15 feet wide, and have an over-all height of approximately 30 feet. About 12 feet of the vertical structure would be underground. It is estimated that 3,700 tons of steel and 300 tons of copper windings would be used in the construction. It is believed that such a machine could produce a deuteron beam 140 feet in length as compared with the 5-foot beam produced by the present 225-ton machine. This next cyclotron is now under construction at the University of California (see pls. 8 and 9) and when it is completed the problem of subatomic energy may be solved and a new power may be released to run the wheels of industry.



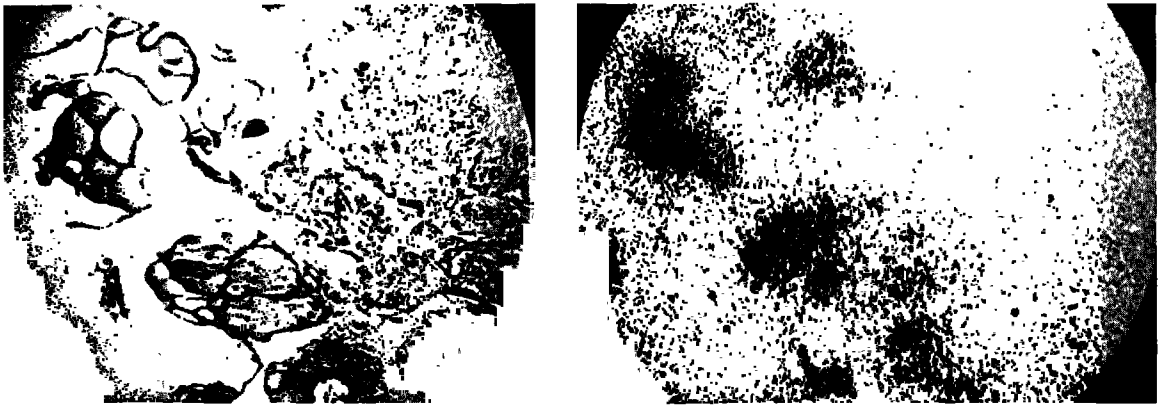
1. THE EXPERIMENTAL ARRANGEMENT FOR THE DETECTION OF THE PRESENCE OF RADIOACTIVE IODINE IN THE THYROID GLAND.

The Geiger counter tube is placed against the neck and the radioactivity is recorded by the instrument on the table



2 RADIO-AUTOGRAPH OF THE DISTRIBUTION OF RADIOPHOSPHORUS IN THE LEAVES OF A TOMATO PLANT.

The leaves were taken from the plant 36 hours after radiophosphorus had been introduced into the solution in which the plant grew. The light areas are the regions where the greatest accumulation of radiophosphorus took place in the leaves



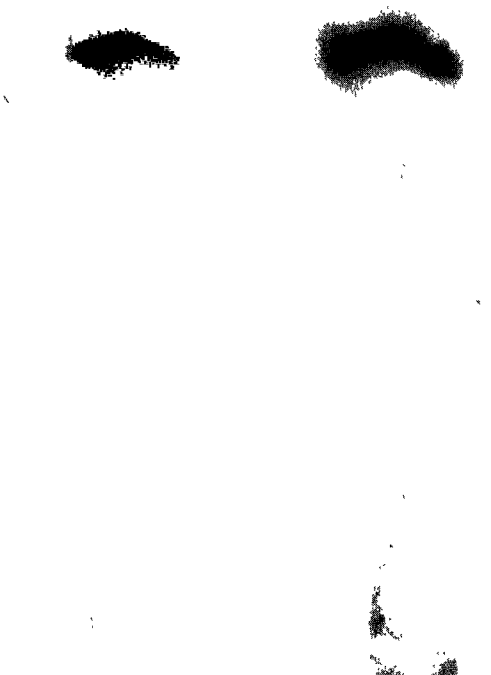
PHOTOMICROGRAPH OF A SECTION OF THYROID TISSUE AND ITS CORRESPONDING RADIO-AUTOGRAPH FROM A PATIENT WITH A CANCER OF THE THYROID (× 60)

The diffuse cellular area covering the right half of the section is made up of cancerous thyroid tissue. To the left are three small islands of invaded thyroid tissue which accumulated most of the radio-iodine. In the radio-autograph shown here the areas of darkening correspond to the regions of greatest deposition of radio-iodine.



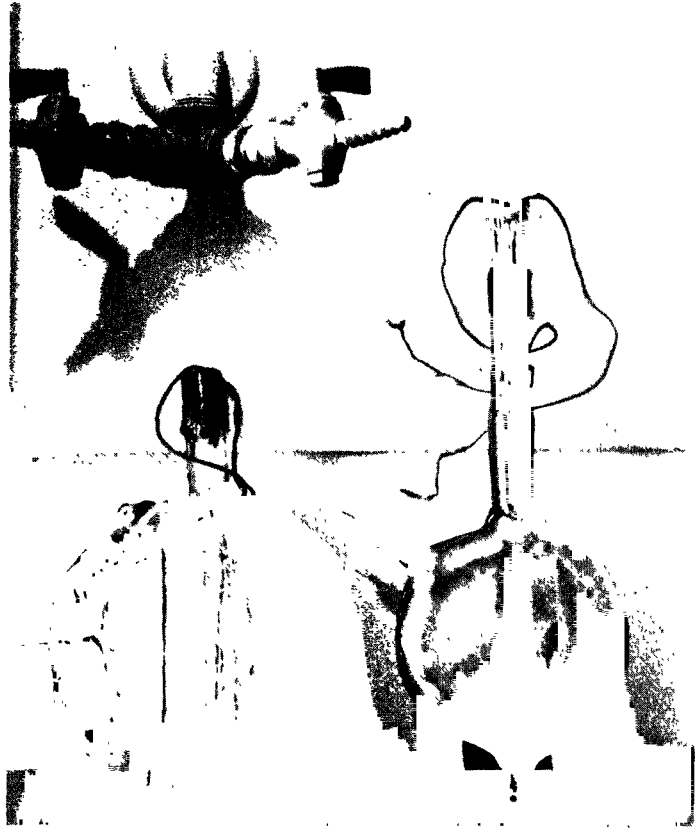
1 THE DIFFERENCE IN DISTRIBUTION OF RECENTLY ABSORBED RADIOPHOSPHORUS AND RADIOSTRONTIUM IN RATS AS DEMONSTRATED BY THE TECHNIQUE OF RADIO-AUTOGRAPHY

On the left the light areas, which correspond to the regions of greatest deposition of radiophosphorus, can be seen to be distributed not only through the bones but also in the soft tissues. On the right, however, the radiostrontium was almost exclusively accumulated in the bones.

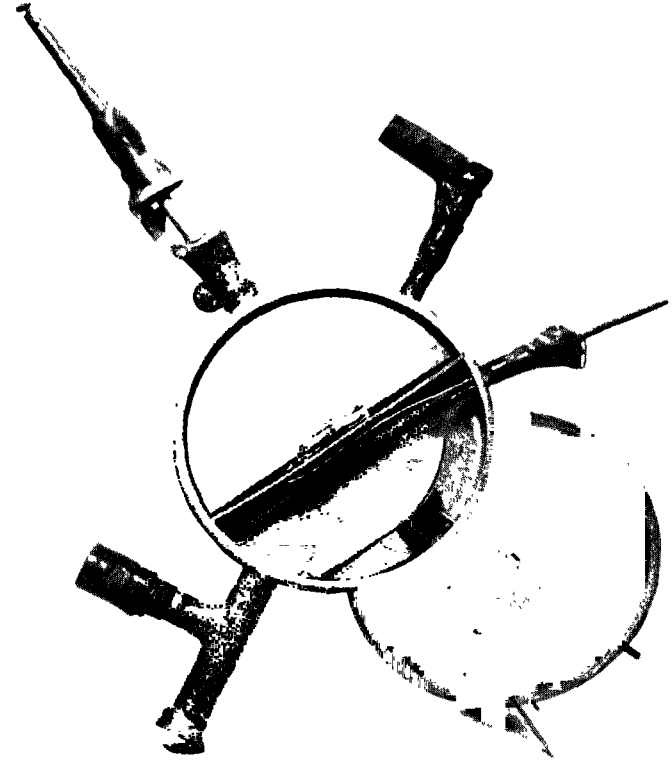


2 RADIO-AUTOGRAPH FROM THIN SLICES OF TWO RABBIT FEMURS.

The one on the right from an animal fed radiostrontium, the one on the left from an animal fed radiophosphorus. The *strontium* is deposited largely in the ends of the femur, while the phosphorus is more evenly distributed throughout the entire length of the bone.



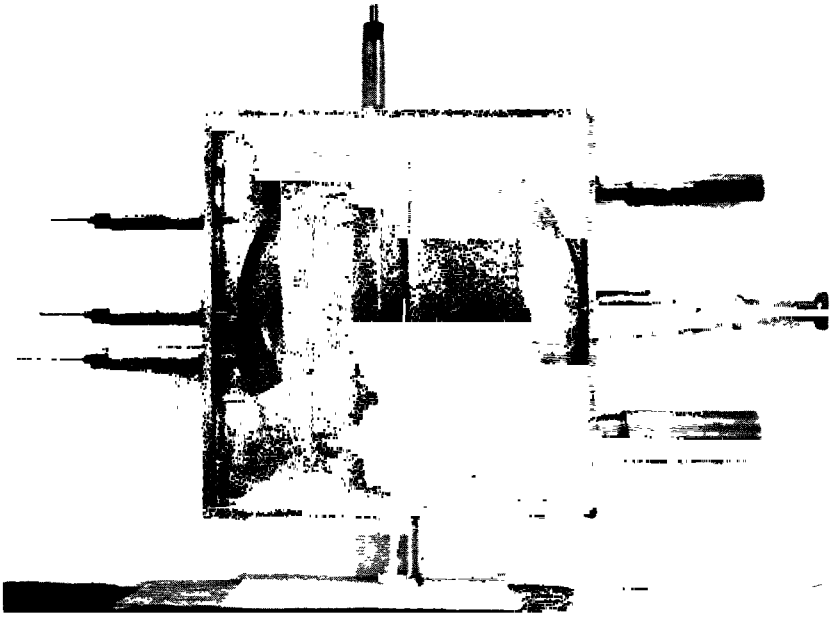
1 Small working model with which the theory of mechanical smashing of atoms was first successfully demonstrated



2 Early working model of the "pan" in which the speed of the atomic bullets is generated

Photographs by Dr. Donald Cooksey, Assistant Director, Radiation Laboratory

TWO PHASES OF THE EARLY HISTORY OF THE CYCLOTRON



1. Another early working model of the "pan" in which the speed of the atomic bullets is generated. Photograph by Dr. Donald Cooksey, Assistant Director, Radiation Laboratory.



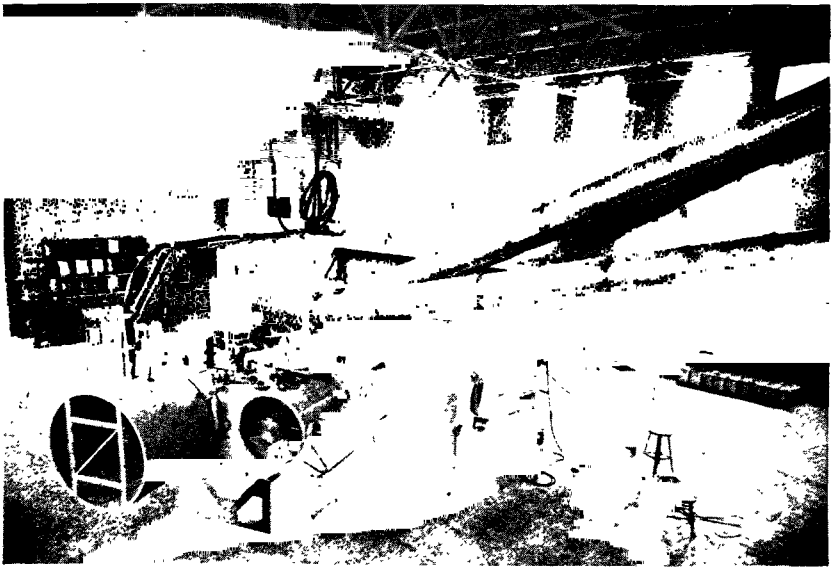
2 The chamber begins to assume somewhat its present form. Photograph by Dr. Donald Cooksey, Assistant Director, Radiation Laboratory.

TWO PHASES OF THE EARLY HISTORY OF THE CYCLOTRON.

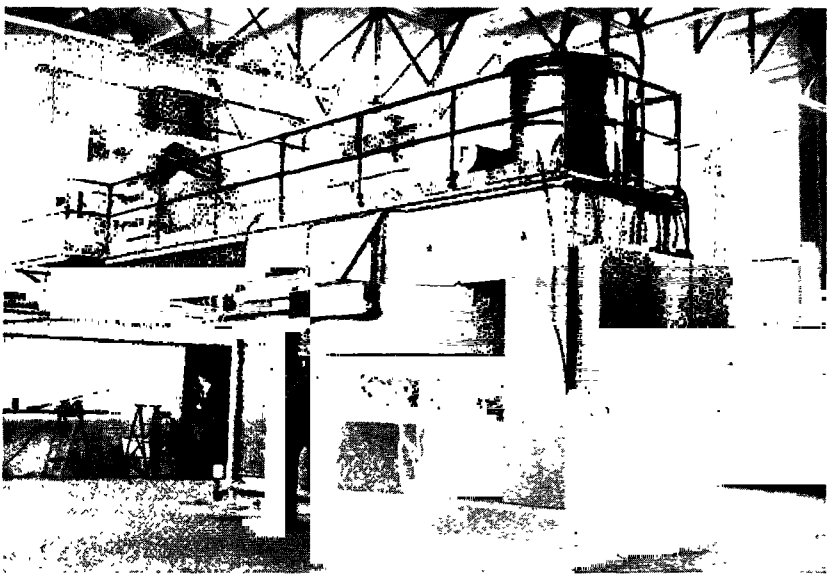


1. THE FIRST LARGE CYCLOTRON WHICH IS STILL IN OPERATION IN THE RADIATION LABORATORY.

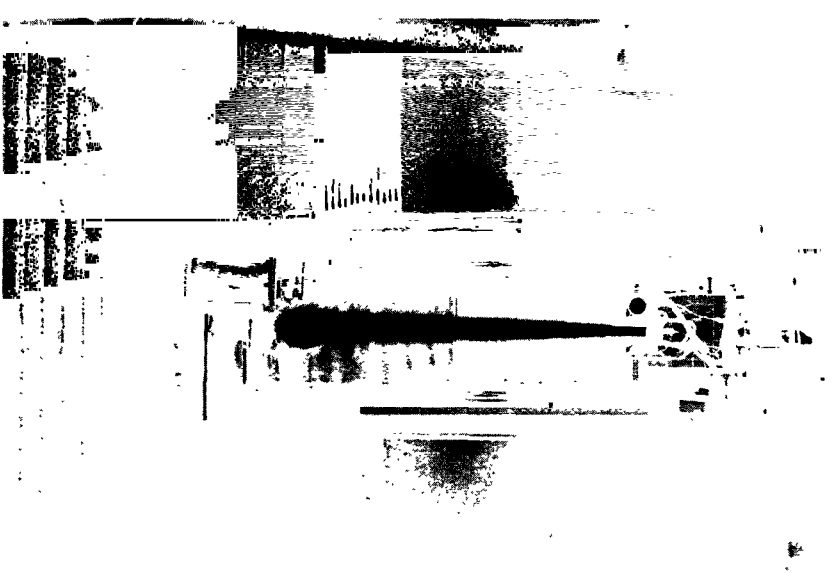
Photograph by Dr. Donald Cooksey, Assistant Director, Radiation Laboratory



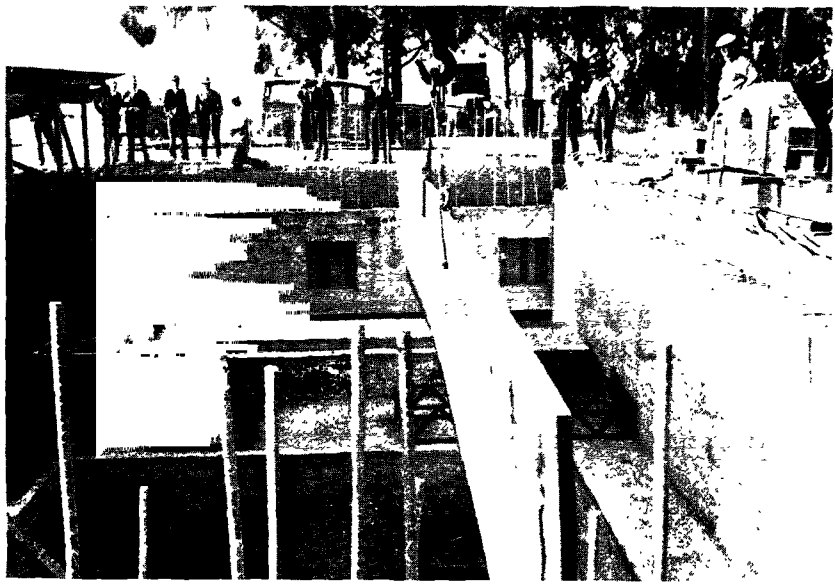
2 THE 225-TON MEDICAL CYCLOTRON



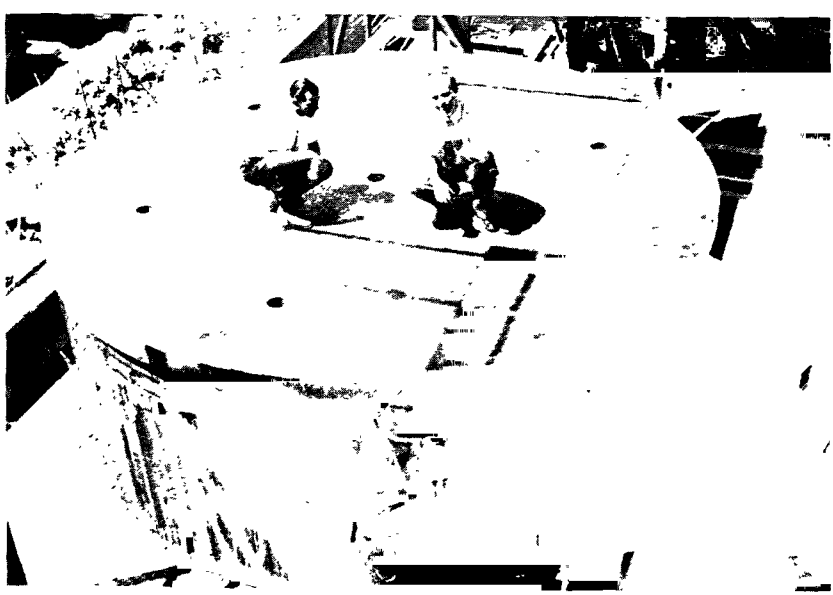
1. THE "WORKING SIDE" OF THE 225-TON MEDICAL CYCLOTRON WHERE NEUTRON-RAY TREATMENTS FOR CANCER ARE ADMINISTERED



2. THE CYCLOTRON RELEASES A BEAM OF DEUTERONS THE "ATOMIC BULLETS" OF TRANSMUTATION



1 The first base plate being placed on the concrete foundation. The plate is 52 feet long, 75 inches wide, and 2 inches thick, and weighs 13½ tons. There is about 1,200 tons of reinforced concrete in the foundation



2 The lower core of the magnet prior to placing of the final pole face. The diameter of the pole face is 184 inches, and the gap between the poles will be 40 inches

PROGRESS PICTURES OF THE NEW GIANT CYCLOTRON AT BERKELEY CALIF



PROGRESS PICTURE OF THE NEW GIANT CYCLOTRON AT BERKELEY CALIF

The magnet as it is at present, still lacking the upper core and pole faces. The magnet frame is 56 feet long, 30 feet high, and 184 inches wide It will contain 4,700 tons of steel

SCIENCE SHAPING AMERICAN CULTURE[1]

By Arthur H. Compton
Professor of Physics, University of Chicago

In no other part of the world and at no previous time in history has life been so greatly influenced by science as in the United States today. This influence extends not only to the supplying of the means of living, but likewise to our thought, our amusements, our art, and our religion.

American civilization is based upon science and technology. That civilization includes great cities, which need for their very existence mechanical transportation, steel rails and girders, electric elevators, refrigeration systems to preserve food, careful control of sanitation, and means of preventing the spread of communicable disease. It embraces great areas of thinly populated but highly productive farm land. Here farmers live relatively complete lives, and supply the nation with an unparalleled abundance and variety of food, because of the agricultural knowledge and tools and convenient communication and transportation that science has supplied. With the help of science, labor and capital are efficient, the Government coordinates the activities of a widely spread people, and our continent has become a national community.

American thinking is strongly influenced by science. Whereas at Oxford it remains doubtful whether science has yet earned a true place in education, at Chicago three of the four main divisions of the university are called sciences. Of the older learned professions, the minister needs to pay close attention to science if he would retain the respect of his congregation; the lawyer who would deal with patents, or corporations, or even crime must acquaint himself with the rudiments of science, and, as for the doctor, the more science the better. Most of the newer professions, such as engineering and architecture, are based upon science. A survey of current literature can leave no doubt but that in American society most of our creative thinking is in the field of science.

[1] Read April 19, 1940, Symposium on Characteristics of American Culture and Its Place in General Culture. Reprinted by permission from Proceedings of the American Philosophical Society, vol. 83, No. 4, September 1940.

It is typical of contemporary American cultural life that good reproduction of the best paintings, and radio programs of the best music are available to nearly everyone. Here is an opportunity for widespread vicarious enjoyment of fine art and music. Yet the soul of art is in its individual expression. While the widespread use of color printing may seem to have discouraged the amateur painter, his place is perhaps taken by the amateur photographer, and the recent rapid growth of school orchestras and bands seems to be ascribable to the growing familiarity with orchestral music as heard over the radio. It is not impossible that use of the radio may mark the birth of a new era in American muscial expression.

On the credit side of the ledger we can certainly count the introduction of new techniques in music and art. Among these may be mentioned the electric "organ," which affords rich, new tone possibilities, and photography and motion pictures. Though the possibilities in these directions are only beginning to be explored, it is already clear that in both still and moving pictures there are new fields opening for both the professional and the amateur. In particular, the possibility of adding action and sound to pictures is comparable in importance with the discovery of representing a third dimension in perspective drawing.

In our recreation we may try to live a primitive life. Having motored hundreds of miles over hard highways, we arrive at the cabin in the wildwood, cook Chicago bacon on a stove using oil from Texas refined in New Jersey, and go fishing with an outboard motor made in Michigan. Or it may be that we go so completely native as to canoe down the river, relying only on our Pittsburgh steel ax and matches made in Ohio from Louisiana sulfur to light our fires, fruit canned in California for our food, and mosquito netting woven in New England to keep off the pests. Though we want to be free from the ring of the telephone and to use the sun as our clock, we must take care that the milk we drink is pasteurized. Thus the American frees himself from technology!

SCIENCE MAKES MEN HUMAN

In his recent book, "Science and the New Humanism," George Sarton shows how throughout history man's cultural growth has followed the gradual growth of his scientific knowledge. In art, except for new pigments, tools, and photographic technique, the American certainly does not excel the Greek nor hardly even the prehistoric European who painted lifelike animals on the walls of his cave. In music the Russian peasants and the natives of Hawaii give us lessons. It is Sarton's contention that those aspects of our culture which have been developing owe their growth primarily to

the advance of scientific knowledge. Thus by learning more and more about the world in which he lives, man has distinguished himself from his animal cousins. If this claim is valid, it means that the primary responsibility for humanizing man lies with science, and that the society in which scientific knowledge is most rapidly growing is the spear point of man's advancing culture.

Let us then examine Sarton's argument more closely. He points out that each stage has been ushered in as some inquirer, more persistent or more fortunate than his predecessors, and building on the foundation of their techniques, has learned new facts regarding the properties of matter, the chemistry of metals, or the laws of mechanics. Thus when we speak of the stone age, the bronze age, the iron age, and the machine age, we are summarizing the growth of man in terms of the tools with which he does his work. Not that mechanical inventions are the only ones. Language and writing are among the most significant inventions of all, giving as they do means of thinking more clearly, of communicating ideas, and of remembering ideas with definiteness. When the invention of printing, telegraphy, the telephone, moving pictures, and the radio are added, it becomes possible for people to share thoughts widely, to become quickly aware of what is happening to all mankind, and to "remember" what has happened to men in the past. A great change thus comes in men's attitudes toward each other. The world becomes almost a conscious unit, very similar to a living organism. Thus even the nonmechanical inventions have found their most effective application through the aid of scientific developments.

Hand in hand with this development of invention has gone the increase in our knowledge of nature. Skillfully made lenses made possible a telescope, and Jupiter was found to be a miniature solar system. As high-vacuum pumps were developed, X-rays were discovered, giving new knowledge of the structure of matter, with resulting advances in metallurgy. "If I saw farther, 'twas because I stood on giant shoulders," is the statement ascribed to Isaac Newton, who clearly recognized the way in which one advance makes possible another.

The knowledge of nature, which from the beginning had been man's gradually but accidentally increasing heritage, at length became the conscious objective of alert minds. Three centuries ago the hobby of a few amateurs, there are now in the United States nearly 2,000 research laboratories, equipped with refined apparatus, where men of the highest training are striving to enlarge our understanding of the world. As a result, our life differs from that of two generations ago more than American life of that day differed from the civilized life at the dawn of written history.

The growing rate of this increase in knowledge and of the resulting social changes may be strikingly presented by using the historian's device of compressing the time scale until the whole growth of man through a million years is concentrated within the lifetime of a middle-aged man of 50. It was then as a child that our man was learning how to use certain odd-shaped sticks and stones as tools. The meaning of sounds became definite as he learned to talk. By the time he was 40 he had developed the art of skillfully shaping stones to fit his needs. Man soon became an artist, and by half a year ago had learned to use simplified pictures as symbolic writing. Some 6 weeks ago the Phoenicians introduced the alphabet, and within a fortnight came the brillant art and science of ancient Greece. Then came the fall of Rome, hiding for some weeks the values of civilized life. Less than a week ago, as the report has it, Galileo dropped the heavy and the light cannon balls from the Leaning Tower of Pisa, refuting a proposition of Aristotle and starting the period of modern science. Three or four days ago the first practical steam engine was built and it was at about this time that the United States came into being. Day before yesterday the laws of electromagnetism became known, which by yesterday had given us the telegraph, the telephone and incandescent electric light. Only last night X-rays were discovered, followed quickly by radium and wireless telegraphy. It was this morning that automobiles came into general use. Air mail began to be carried only at noon today. Popular short-wave broadcasts, practical color photography, and fluorescent lighting have been with us for only an hour. It is clear that our American scene is staged in the midst of a period of unparalleled advance in science and rapidity of social change.

AMERICAN CULTURE IS THAT OF A CHANGING SOCIETY

Even before the outbreak of the present wars, America had become the leader in most fields of scientific endeavor. The tradition of the pioneer has made it relatively easy for the American to alter his habits as required by the introduction of new techniques, with the result that in this country social changes have gone ahead with a speed not found elsewhere. Our culture is thus that of a new community, with our customs and ideas only partly adapted to the rapidly changing conditions of life.

For a week I have been living in an apartment on a corner by which a streetcar clangs its noisy course. When first installed, these cars gave the rapid transportation that made the city possible. Now the demand is insistent that the streetcars be replaced by quieter buses that will permit conversation by day and sleep by night. Thus the first application of technology was to meet the primary

need of transportation; but eventually the refinements come that add to life's enjoyment.

Our older habits no longer fit the new conditions of life, and we have not yet learned how best to use the new possibilities placed at our disposal. Nor as long as such rapid changes in our social life continue can we hope to make a completely satisfactory adaptation of our mode of life. For as one aspect of the problem becomes solved, changes will lead to maladjustment somewhere else. It would for this reason be futile to hope to attain within the next generation an art of living in a technological world that can compare in refinement with the classic culture initiated by the Greeks and developed through centuries of such tradition as that carried on by European and English society. In course of time, though it may require centuries, we may expect the development of science to approach a new plateau of knowledge and invention. Then we may hope again to refine our mode of living to fit precisely the conditions of our greater world.

Does this prospect of generations of incomplete adaptation, with resultant discontent and hardship seem discouraging? One is reminded of the legend in which the people complain to Daedalus that the steel sword he has given to King Minas will bring not happiness but strife. Daedalus replies, "I do not care to make man happy, but to make him great." For those who have courage, the new powers thus given by science present a challenge to shape man's life on a more heroic scale. Here is a vision of a new world which only the brave may enter.

Yet we can thus appreciate the dread felt by those who have followed the tradition of classic culture as the life they have loved and whose values they have cherished is threatened by the advance of technology. They see science replacing the human interests present in literature, art, and music with technological developments in which the human factor becomes less and less significant. The most fundamental values of morality and religion are ruthlessly shaken, with the implication that their value is negligible. It is just because so many scientific men seem blind to these human difficulties that one feels the greater concern lest in following science mankind may lose its soul.

There is a passage in Plato's Phaedo in which Socrates describes his early interest in physics and how he had found that physics fails to account for the important things in life. Thus, he explained, Anaxagoras would say that Socrates sat on his cot waiting to drink the hemlock because of certain tensions of tendons acting on his bones. The true reason was rather because he had been condemned by the people of Athens, and as a man of honor he could not creep stealthily away. Such moral forces as honor were not to be explained

by science; yet it is these forces that shape men's acts. Since it did not meet their human needs, the followers of Socrates and Plato abandoned science, and the study of the truths of nature was forgotten for a thousand years.

We have now once more come to fear the unhuman implications and the inhuman abuses of science. Yet science has enriched our lives and has helped us catch a vision of a new and better world. Shall we then again give up science and with it the tools by means of which that better world may be attained?

The truth is that we cannot cast away science even if we would. In a time of intense social strife the knowledge of the world that we call science is a source of tremendous strength. Nothing is so clear as that a nation which abandons science must soon become weakened. The world's leadership must go to those who are served by science and technology. That we shall live with science is thus decreed by the immutable laws of evolution.

THE HUMAN MEANING OF SCIENCE

For those who know science, its inhumanness is a fiction. It serves to satisfy the human hunger for a better understanding of man's place in his world. In this age when men throughout the world are trying to formulate a philosophy by which they can live, it is to science that they are turning with confidence in its truth. But perhaps of greatest importance is the fact that science is making man develop into a social being.

One of the most striking of biological phenomena is the change of man in a short thousand generations from an individualistic to a social animal. As has been indicated above, this change is due largely to the development of science and technology. If we would assess the cultural significance of science, it is thus important to consider what the more specific directions may be along which this social evolution will proceed. It is clear that we may expect those modifications in our mode of life to survive which give strength to the social group. Among these strengthening factors three may be emphasized. These are: knowledge, cooperation, and a common objective.

In science and technology lies our approach to the laws of the world of nature and the application of these laws. Enough has been said regarding the strength that comes through such knowledge. In a highly competitive, warlike world, that society cannot long survive which neglects the truths of science.

Without cooperation, knowledge cannot be made effective. If men divide into antagonistic groups, it becomes terribly destructive. Experience as well as theory has shown the superior strength of those social groups which work together. The evolutionist thus sees as inevitable the growth of social cooperation.

Just as the automobile demands sobriety, or congested life makes necessary careful sanitation, so the mutual dependence of a technological civilization implies consideration of the rights of others. Breasted has shown how the growth of community life along the Nile stimulated among the Egyptians the "dawn of conscience." Cheyney, in his retiring presidential address before the American Historical Association, lists prominently among his "laws" of history the trend toward a greater consideration of one's fellows as society grows more complex. Thus in the technological society of which American culture is a supreme example, science and industry are emphasizing as never before the need of the will toward cooperation, that is, of the love of our neighbors. Perhaps the urgency of the universal acceptance of this central doctrine of Christianity is not generally recognized. This is merely because the social implications of our increasingly complex life have not yet become evident within the brief decades of the world's growing social unity.

Most significant of the factors that give strength to man is, however, the vision of a goal which he recognizes as worthy of his supreme effort. If we would truly live, we need a purpose. To many of its followers, science gives a basis for the appreciation of man's place in the universe. It helps him to see himself as he is, a creature with animal limitations, but with godlike powers, sharing with his Creator the responsibility for making this world a fit place for life. The man of science may not feel qualified to choose for others that which gives life dignity and worth; but he can at least supply the data on which that choice must be made. How can we correctly orient ourselves without learning the facts about the world and dispassionately considering their implications. It is, I believe, in just this direction that science must ultimately make its greatest human contribution. Science must clarify the vision of the seers who would point out to us the goal of life.

It is noteworthy that these things which give strength to society are likewise those that make life worthwhile, the understanding of man and nature, the love of one's neighbor with the acceptance of responsibility for his welfare, the finding of a goal worthy of our best efforts. Though American technological civilization may lack the refinements and nice adjustments which perfected the classic culture, its growth is toward the greater social development of man. In this sense it is truly humanistic.

The role of science in American culture is thus threefold. First, it supplies more adequate means of life, giving men longer life, better health, and a richer variety of experience. Second, it stimulates man's social growth by rewarding more abundantly cooperative effort and

punishing more severely his antagonisms. Third, science serves as a direct means of expression of the human spirit.

It was the greater variety of life that was the great reward of science seen by Francis Bacon as he wrote in his "New Atlantis":

> The end of our society is the knowledge of causes, and the secret motions of things, and the enlarging of the bounds of human empire to the effecting of all things possible.

After three and a half centuries of experience with modern science this aim has been so realized that the president of one of our leading technical institutes can say,

> In the last 50 years physics has exerted a more powerful beneficial influence on the intellectual, economic, and social life of the world than has been exerted in a comparable time by any other agency in history.

It is its responsibility for man's social evolution which leads Sarton to describe the growth of science as the central thread along which may be traced the biography of mankind.

To the man of science himself, however, it is as an effective method of developing the human spirit that he values his science. His study affords exercise of imagination and broadening of perspective. Whereas to Plotinus it appears that

> It is through intuition rather than through reason that we may approach our highest aspirations,

the scientist finds that in the discipline of unprejudiced search for truth lies the beginning of wisdom. Thus, in the words of Thomas Huxley:

> Science seems to me to teach in the highest and strongest manner the great truth which is embodied in the Christian conception of entire surrender to the will of God. Sit down before a fact as a little child, be prepared to give up every preconceived notion, follow humbly wherever and to whatever abysses nature leads, or you shall learn nothing.

This is the aspect of science recognized by the Greek philosophers, who would seek "of what and how the world is made" in order that they might find a better way of life. To a certain degree this humanizing aspect of science is esoteric, since it can be fully appreciated only by those who have themselves submitted to the discipline required to share in the effort to widen the horizons of knowledge. Certain aspects of science, notably astronomy, have been more effective than others in opening the way for many amateurs to take part in their enterprise. As in art and literature, here in advancing human understanding is an opportunity for enriching life. With finding new knowledge comes the satisfaction of knowing that one has not only made a permanent addition to man's heritage, but that the new knowledge is a seed that will grow from more to more. With Democritus the scientist can truly say, "I would rather learn the true cause of one fact than become King of the Persians."

MATHEMATICS AND THE SCIENCES[1]

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INTRODUCTION

At the outset I wish to express my very sincere appreciation for the evidence of trust on your part which makes this occasion possible for me. It is quite a surprise when a group of scientists so honor a teacher of mathematics, for it is a moot question as to whether mathematics is a science. It is more than a surprise when that teacher is your speaker, whose association with science has been more that of a worshiper from afar than he likes to have to admit.

The duties of this office resolve themselves in large part to the retiring address which brings us here tonight. Upon asking myself what I might say to you that might in part compensate you for coming here, I thought it pertinent to consider with you the relation between mathematics and the sciences. With this purpose in mind I asked a philosopher colleague what he considered that relation to be. His reply was quick and pointed. "There is no relation," he said, "science thinks a thing in terms of other things; mathematics thinks a thing in terms of itself." His inference was that the two are mutually exclusive. This was very discouraging.

The history of science, however, does not seem to bear out the philosopher's contention. Until the time of Galileo (1600) that history is practically a history of mathematics. Although we have some knowledge of perhaps 6,000 years of mankind's intellectual activity, we search in vain for any trace of science before 2,500 years ago. True we have the pyramids, some 5,000 years old, and their structure indicates the employment of scientific ideas. We have, too, the Rhind papyrus, 3,500 years extant, and within its pages a kind of mathematical science. But the first scientist to emerge from the mists of antiquity was Thales, the mathematician of 2,500 years ago. Almost contemporary with him is Pythagoras, a strange mixture of scientist and pseudo scientist. Two centuries later came

[1] Retiring address of the president of the North Carolina Academy of Science, Wake Forest, N. C., May 5, 1939. Reprinted by permission from the Journal of the Elisha Mitchell Scientific Society, vol. 55, No. 2, December 1939.

Democritus with the beginnings of an atomic theory which even the opposition of an Aristotle could not down. Another century brings us to Euclid, but we must wait yet another century until, around 200 B. C., appeared that resplendent figure of old, Archimedes, bringing with him the law of buoyancy, the principle of the lever, the discovery of light reflection and the cry of "Eureka," which Whitehead says should be celebrated as the awakening cry of mathematical physics.

In the 17 centuries from that day to the time of Copernicus (1500) physics was to remain at practically a standstill. In another century these latent stirrings of the scientific spirit were brought to light for the first time in the father of modern science, Galileo Galilei, whom we know so well that we invariably call him by his first name. Important it is that he should be the first to formulate inertia, to discover the law of falling bodies, to invent the pendulum and the telescope, to discover the four satellites of Mercury and the sunspots. More important still, says Millikan, that he should see "that force is proportional not to motion, but to the rate of change of motion, an idea the most profound in human thought." I dwell on Galileo because he is generally regarded as the originator of the modern viewpoint in science. He, asserts Einstein, "saw that all knowledge of reality starts from experience and ends in it." Thus, as Whitehead so aptly puts it, "the world waited 1,800 years from Archimedes to Galileo for someone who could relate abstract mathematical ideas to experimental investigation of natural phenomena."

Modern scientific inquiry as such seems to have begun with Roger Bacon in the thirteenth century. Leonardo da Vinci was indeed a voice crying in the scientific wilderness of the fifteenth century. Tycho Brahe's tables of 1601 were a first step in scientific observation. By means of them one could tell the position of the planets. It took a Kepler (1610) to see in them the three fundamental laws of planetary motion. Kepler could then tell us where the planets would be. In 3 inches he condensed the voluminous tables of Brahe, a tremendous scientific advance.

And then came Newton! Whitehead says that science came of age that day with Newton in his garden. Einstein regards Newton's laws of motion as expressed in differential equations as the "greatest advance in thought that a single individual has ever been privileged to make." He says further that Newton was the first creator of a comprehensive, workable system of theoretical physics. This one man, he continues, gave intellectual guidance to science for 200 years." Perhaps no man, then or since, has known Newton's scientific viewpoint as has his modern prototype, Albert Einstein, who has done more than any man to supplement his work. He says of Newton,

"He believed that the basic laws and concepts of his system could be derived from experience. This is the meaning of '*hypotheses non fingo.*' Newton was uncomfortable about absolute space, absolute rest and action at a distance, since he found no basis for them in experience. The successes of his theories prevented discovery of the fictitious character of his foundations."

Daniel Bernouli (1700) following shortly after Newton has been called the founder of mathematical physics.

From this era dates the origin of organic chemistry. Lavoisier (1743–94) transmuted alchemy into a rational science. Perhaps, as his judges said when he faced the guillotine, the republic had "no need of savants." Certain it is that chemistry had great need of Lavoisier.

Mathematics through the calculus as we know it today was shaped largely by the hand of Euler (1707).

Sedgwick and Tyler state in their history of science that at the beginning of the nineteenth century general physics and chemistry were "still in the preliminary stage of collecting and coordinating data, with attempts at quantitative interpretation, while in their train the natural sciences were following somewhat haltingly."

Geike adds that at this time "geology and biology were not yet inductive sciences."

But the stirrings of science in the eighteenth century projected themselves into the nineteenth. Dalton (1803) with his law of multiple proportions for the formation of compounds supplied the first scientific approach to the atomic theory.

Lyell with his publication of his "Principles" in 1830 raised geology to the dignity of a science.

Biology was admitted to the union of sciences in the Victorian age through the efforts of Darwin, Spencer, Huxley, Wallace, and others.

By 1850 the older universities had founded scientific schools. Academies of science began to be formed. The public by the opening of the twentieth century was science-minded. A new era was about to dawn.

This new era took the form of a new conception as to the structure of matter. There were significant undercurrents in the world of physics. Sir Humphrey Davy made what he called his greatest discovery, Michael Faraday. Faraday (1791–1867) discovered the principle of magneto-electricity, and originated the electromagnetic-field theory. The world was little aware of these tremendous happenings. Even at a time when the Atlantic cable was in operation Gladstone could (and did) ask Faraday whether electricity had a use. And Faraday replied, "Why Sir, there is every probability that you will soon be able to tax it."

In 1850 Maxwell placed a mathematical support under Faraday's theories, to be followed by the experimental verification of Hertz.

Joule (1818–89) found a mechanical equivalent for heat, namely, energy, giving the world the first law of thermodynamics.

Plank gave a description of radiation as incapable of emission in aught but units, the quanta. In this quantum theory fractions of a unit of energy simply do not exist.

De Broglie and Schrodinger combined the energy theory of Einstein with the quantum theory of Plank and compelled the joint wave-particle view of the atom. (Since then the physicist has been accused of teaching the wave theory on Monday, Wednesday, and Friday, and the particle theory on Tuesday, Thursday, and Saturday.)

Heisenberg proclaimed the doctrine that nature abhors not a vacuum so much as it does accuracy and precision.

Dirac extended the uncertainty principle of Heisenberg to the entire realm of atomic physics.

Pauli furnished us with his exclusion principle.

Millikan and Cameron gave us cosmic radiation.

Minkowski offered his space-time world.

Einstein supplemented the Newtonian mechanics, proclaimed the invariance of natural laws in inertial systems, the constancy of the velocity of light, the abandonment of simultaneity, the identity of mass and energy, claimed absolute motion incapable of detection, related time and motion, connected space and matter. Gravitation, that most elusive of concepts, appeared as the curvature, or crumpling, of a space-time continuum. But the electromagnetic fields were not expressed in the field equations of general relativity. Later came a field theory in which gravitation and electromagnetic radiation were welded together. Only the expression of the atomic structure in terms of the field theory was, and still is, missing.

Here we are, and what a long way we have come. Let us examine some of the high and low places along the path. Let us see again something of the view from a few of the peaks and depressions along the way. Let us inquire of Mathematics, the guide in this long and fascinating journey.

CONTINUITY

Perhaps we never realize its subtlety until we really try to find out the meaning of continuity. The writer of radio script uses the term to refer to his product. We have heard his programs. Can such an idea be hedged about with difficulty? As is so often the case, an understanding of the concept implies an understanding of its opposite. The opposite of the continuous is the discrete.

Long ago there lived an excellent gentleman named Zeno. It was back in the time of the Pythagoreans, 500 years before Christ. This

Zeno saw the conflict between these opposites, and used what he saw to deny the possibility of motion, to discourage placing bets on Achilles in his historic race with the tortoise, and for other strange and bewildering purposes. Even today one doesn't just rush in to show where Zeno was wrong. In his antinomies are found the baffling ideas of the infinite, the deceiving implications of continual divisibility. Down the years we trace these difficulties like a colored skein in the pattern of scientific thought. They face the scientist in his effort to understand the constitution of matter. Is this paper from which I read smooth and unbroken, or is it made of discrete particles bounding about hither and yon—a veritable beehive? The physicist leans to the latter view. (This opinion may help explain the nature of what is being read from these pages.) What, then, about action at a distance? How are light, radiation, energy, gravitation conveyed from here to there? What? No ether? Can we have ether without continuity? If the ether is a jellylike mass, is it not composed of particles? If it is composed of particles, will not the quantum behavior of matter nullify the continuity of the action? If we have a continuous exciting cause, is it not strange that energy should emerge in units (quanta), or not at all? Are there no fractions? The physicist says, "No, no fractions." De Vries claimed that evolution proceeds by "explosions." But Darwin, Newton, Kant, Leibniz all believed in continuity. Plank's quantum theory replaces a continuum of states in an isolated system by a finite number of discrete states.

The mathematician has been through—I should say, is in—this same turmoil. He has never fully recovered from the Pythagorean shock of the irrational. For a time it was thought that Weierstrass, Dedekind, and Cantor had laid the spectre, but the contrary views of Knonecker, Brouwer, and Weyl on the calculus of Leibniz and Newton, the feeling that this calculus is making "bricks without straw," must at least have a hearing. The critics of continuity claim that nothing which cannot actually be constructed by a finite number of steps can hope to lead to a discipline free of paradox. They maintain that all analysis must eventually subject itself to the domination of the positive integer. Karl Pearson, one of the nonmathematical scientists who shares this view, states the position thus, "No scientist has the right to use things unless their existence can be demonstrated."

Some may meet these difficulties by what has been called "a continuous but discreet silence."

Certain it is that a Thomas Wolfe may write "Of Time and the River" with a much more glib assurance than may an Einstein.

Simple things these—in time such a perfect continuity; in number such discreteness (I came near saying "discretion"), and in the shadows an infinity trying to bridge the gap.

CAUSATION

Jeans maintains that the "steady onward flow of time is the essence of the cause and effect relation." It is but natural, then, that when continuity is in question, causation should take its place under the microscope of scientific scrutiny. There is more at issue than the mere post hoc ergo propter hoc argument. We are so used to drawing inferences from data, that it is hard to realize on what flimsy grounds many of our conclusions rest. It is hard, too, to see how we may do intellectual business at all without the ability to infer effect from cause. The great seventeenth century of Galileo and Newton encouraged the scientist to think of causation as something on which he could definitely rely. Modern physics takes the position, so ably formulated by Pearson, that causation is intelligible only in the perceptual sphere as "antecedence in a routine of sense impressions."

With the precision of measurement in studying natural phenomena came the realization of the statistical character of those measurements. Into the relations connecting the numbers arising in this way began to enter questions of doubt. The descriptions of the phenomena exhibited by the relations were seen to be more exact than the uncertainty of the data warranted. It began to appear that the descriptions described little more than what Weyl has called "statistical regularities." Pearson has put it thus bluntly, "In the order of perceptions no inherent necessity can be demonstrated * * * necessity has a meaning in the field of logic, but not in the universe of perception * * * causation is neither a logical necessity, nor an actual experience."

This position seems at first glance to be at variance with the "if this, then that" of mathematical disciplines. The causation which inheres in logic, whose presence we so naively hope for in our scientific thinking, seems actually to emerge in the tenets of the mathematician. How, then, may the scientist fit data patently statistical in character into mathematical form, clearly nonstatistical in character? If, as Pearson claims, "contingency and correlation replace causation in science," how does the mathematical equation tell us a true story of natural phenomena? Pearson answers this in part by saying, "Contingency is expressed in a table with cell-dots forming a band. This band viewed through an inverted telescope gives a curve. This curve is the mathematical function."

In the language of the mathematician, the scientific relation approaches the mathematical formulation asymptotically. Perhaps a more nearly correct statement is that both the scientific data and the mathematical description near each other in a process of successive approximation which would warm the heart of a Poincare.

Although many scientists feel, with Jeans, that the advent of Plank's quantum mechanics has dethroned continuity and causation, they in large measure share his belief that the appeal to a purely statistical basis may be a cloak for ignorance and that cause and effect of an unknown character may actually be in operation.

DETERMINISM

One would expect that questions about cause and effect should have philosophical implications. There arise the old questions of determinism and freedom. Determinism, according to Dantzig, "consists of the assumption that, given any natural phenomenon, the various features that characterize it are completely determined by its antecedents. The present knowledge permits prediction of the future course." "Each extension of the law of causation," says Jeans, "makes belief in freedom more difficult." Pearson claims that "our belief in determinism is the result of supposing sameness instead of likeness in phenomena." Eddington asserts that "physics is no longer pledged to a scheme of deterministic law." When asked why one magnet repels another, Whitney replied, "By the will of God," and added "science can enslave us, or it can make us free, but it is we who make the choice." Others hold the view that our bodies and our minds are as physical as inert matter, made of the same chemical elements to be found in the remote stars, subject to the same inevitable laws; that the same determinism which holds for them holds also for us. Compton, speaking at the University last November, refuted the claim that man's actions depend on physical law. But he claimed it a vital question for science to find out whether man's actions are determined; and if so, by what factors. He maintained that it is no longer justifiable to use physical law as evidence against freedom.

Into this confused picture comes mathematics with its law of averages and its probability theory. Almost within the last decade the uncertainties of the situation have been amplified by Heisenberg into an Uncertainty Principle, which says, "To any mechanical quantity Q there corresponds another quantity P in such a way that the product of the uncertainties in our knowledge of Q and of P can never be less than a certain constant h, Plank's constant; hence the more accurately we determine Q, the more ignorant we are of P." In the Newtonian mechanics a knowledge of the position and of the velocity of an electron at an instant determines the future position of that electron, but Heisenberg assures us that we can never know both. The more accurately we determine the position, the less accurately we know the velocity; and vice versa. This concept of uncertainty seems to put the coup de grace on determinism. But who

shall say that the very law of averages which replaces determinism may not itself be as great a despot as the dictator which it displaces? May there not be still a new determinism dominated by probability, just as there may be a new causation whose source is unknown to us? Or shall we, with Compton and others, align ourselves with freedom because, as he says, "I find reason to believe in freedom, and wish to find whether such freedom is consistent with the recognized laws of physics." It would be a fine irony, indeed, if science, the greatest liberator of men's minds, denied to itself that freedom which it has so unstintingly given to mankind.

LAW

This outlook brings us to consider our ideas of law anew. When we say law, what do we mean? Do we think of brass buttons and a uniform? Do we think of statutes to which as citizens we owe obedience? Do we think of natural law, such as Newton's universal law of gravitation, or of mathematical law, such as Gauss' law of quadratic reciprocity, or of the philosopher's definition: "Law is Unity in action difference"?

Weyl tells us that the mathematical lawfulness of nature "is a revelation of Divine reason." "The world," he says, "is not a chaos, but a cosmos harmoniously ordered by inviolable mathematical laws." We speak of Boyle's law for a perfect gas, of Kepler's three laws of planetary motion, of Dalton's law of multiple proportions and many, many other laws. The scientist maintains that his chief concern is the discovery of nature's laws. Just what does he mean by that? Is civil law one thing, and natural law another? Does law mean one thing to some of us, and quite another thing to others of us? Or, is there a philosophic pattern behind all law?

In trying to understand the world we live in we observe and we experiment. We assume the validity of sense perception. We assume that normal human beings observe and experiment in much the same way. If we have ever listened to witnesses testify in court, we know just how much of an assumption that is. And furthermore, what, pray, is a normal human being? Many of us feel that all the knowledge that we obtain of natural phenomena comes through the senses, despite Pearson's continued insistence that in thinking we deal not only with sense impressions but with stored-up opinions of former sense impressions. We measure with all the uncertainties attendant thereto; we think, or try to, amid all the doubts above mentioned as to continuity and causation and determinism weighing upon us. How in this atmosphere can we get at law?

The mathematician stands serene in his confusion. To him law is simply the matter of an invariant under a set of transformations.

This invariant incorporates the unity, if any, present in the differences of action in the situation in question. This unity answers the question as to how we may see the permanent in the transitory. The scope of it tells us how we may see the general in what is particular.

In civil law we have to make the statute. Whether we like it or not, that statute may be broken. Still in the changing pattern of civil law the statute formulates what unity is possible in the diversity of action which it seeks to control. In natural law these differences in action take the form of the great dissimilarities in observed phenomena. The unity is the common part, if such there be. The natural law expresses this unity amid the action differences. Its form is never final until it partakes of the form of the mathematical invariant.

POSTULATION

Reflections on the nature of law bring forcibly to our minds the postulational character of our thinking. We do well to examine the meaning of our most fundamental concepts as well as the lines of argument leading to our most important conclusions. Every science has its undefined terms. Aught else is an infinite regression. When analysis fails, we rely on the properties of our concept to define it for us. In setting up the discipline for a science, some of the propositions must be accepted without proof for similar reasons. The criterion for choice is simplicity. This is not as simple as the name indicates. By simplicity, as used here, is meant logical simplicity. As Einstein so aptly words it, "By 'simplest' we mean that system which contains fewest possible mutually independent postulates, or axioms." This attitude of modern science is far removed from Newton's hypotheses non fingo. It is an attitude undoubtedly provided by the mathematician. Einstein continues, "Nature is the realization of the simplest conceivable mathematical ideas. I am convinced that we can discover by means of purely mathematical constructions, the concepts and the laws connecting them with each other, which furnish the key to the understanding of natural phenomena. Experience may suggest the appropriate mathematical concepts, but they most certainly cannot be deducted from it. Experience remains, of course, the sole criterion of the physical utility of a mathematical construction. But the creative principle resides in mathematics."

Such a postulational approach to mathematical thinking was seen by Euclid insofar as our inability to define satisfactorily all our terms. The fact that even a mathematician cannot prove everything was not formulated until Pasch, almost in our own time. Now the necessity of a postulational approach to both definitions and theorems is a universally accepted tenet of the mathematician.

SYMBOLISM

Whether we agree to this postulational so-called simplicity, we can have no doubt of the existence and efficacy of symbolism in both mathematics and the sciences. The desire for constructibility, so ably championed by Knonecker, has found its way into our search for an understanding of the nature of matter. We hear Lord Kelvin exclaim that he "can understand nothing of which he cannot make a mechanical model." To meet this desire we have the dynamic Rutherford-Bohr model of the atom and the static Lewis-Langmuir model. But we are told these are too simple and definite to be regarded as other than intellectual conveniences. The ether is symbolized for us as a jellylike mass with remarkable properties. We are warned, however, that the universe is not completely picturable in a graphical sense. Radiation and gravitation elude such a mechanical description. We speak of particles and waves as describing the behavior of light and radiation, but we are reminded that the electron is only a symbol for convenience of speech. Eddington tells us that matter and all else in the physical world has been reduced to a "shadowy symbolism." When we ask what the symbols stand for, the reply is that it doesn't matter. (One is reminded of the story that is told of Professor Lefevre, of the University of Virginia. He is said to have greeted his philosophy class one fine morning with the startling pronouncement, "What is mind? No matter. What is matter? Never mind.") "Physics," continues Eddington, "has no means of probing beneath the symbolism. Nor does one have to understand the symbols. What we have to understand are the conditions to which the symbols are subjected." The symbols themselves are dummies. Any other would do as well.

The mathematician is thoroughly in accord with this use of symbolism. He has likened his subject to a game of chess. The rules of the game play the role of postulates. In such a game Bell tells us there is no question of "truth"; there is merely a question as to whether the rules have been complied with. To Hilbert mathematics is "a game played according to certain simple rules with meaningless marks on paper."

PREDICTION

We have heard of old that a prophet is not without honor. For the man in the street the ability of science to predict the future holds a particular fascination. He is thrilled by the story of an Adams and a Leverrier working apart, each computing from the perturbing influences of an unknown source on Uranus, the position of a new planet, Neptune, just 52 minutes from where Galle later found it. He reads of the electromagnetic waves predicted by Faraday

and Maxwell and verified by Hertz. He has heard of the more recent prediction by Einstein of the shift toward the red end of the spectrum, caused by the deflection of light in a gravitational field, verified in the solar eclipse of 1919. These and many others, such as Mendelejeff's prophecy as to the discovery of gallium, scandium, and germanium, and such as Hamilton's prediction of conical refraction, have cast science in the role of one of the major prophets. Even Pearson concedes science the ability to predict, as well as to describe.

Mathematics provides in its differential laws a pattern for these predictions. "A differential law," says Einstein, "tells us how the state of motion of a system gives rise to that which follows it in time." "If we know how the velocities and accelerations depend on position, we can trace out the past and future of our universe," says Pearson. This is done by means of differential equations with proper boundary value conditions. The chemist does it when he predicts the position of the electron in its orbit. The astronomer does it when he predicts the position of the planet in its orbit around the sun. Despite Heisenberg's uncertainty as to our ability to measure both position and velocity, the schedules of the planets are much better known than are those of the crack Chicago to New York trains.

INVENTION

Science is known to many only for its inventions. Much of its popularity with the masses is due to the added comforts and enjoyments with which it supplies them. Their eye is open for the so-called practical things of science. The auto, the radio, and the thousands of gadgets which give us our arm-chair civilization, endear science to the heart of the multitude.

But this has not been the path of scientific progress. These things have usually been but byproducts. Hertz little thought when he verified Maxwell's electromagnetic waves that he was laying the foundation for radio. Perhaps as often the practical leads back into the fundamental principles, as do the principles lead to invention. Again, when the scientist thinks himself most theoretical, he may be near a very useful practicality. "Indeed," says Richards, "the developments of the wave mechanics now in progress may be fraught with graver practical consequences for humanity than the approaching commercialism of television or rapid transoceanic passenger flying."

It is an old story to the mathematician, whom the cry of "practicality" fails to arouse. Archimedes, tracing his conics in the sand when Marcellus' soldiers snuffed out his genius, had no thought of a Kepler using them to describe the paths of the planets. Argand, Gauss, Wessel in their abstract imaginings about the complex num-

ber little fancied that they would later in the hands of Maxwell place a firm footing under modern electrical theories. Riemann, Cayley, and Sylvester had no thought that they were preparing the way for Einstein. Sturm and Liouville had no concern for the wave mechanics of De Broglie, which their researchers made possible. The meditations of Cayley appear in the modern theories of Heisenberg and Dirac. Fermat, Gauss, De Moivre, Pascal could not possibly have foreseen that their probability theory would one day revolutionize physics. Indeed, the theory of today is so often the practice of tomorrow. If it were not, it would be no great matter. But, as Philip has said, "it is only against the background provided by the pure research of yesterday that the technical problems of today can be viewed in their proper setting and tackled with a reasonable prospect of success. Work in the pure sciences, however remote from the practical issues of the moment, is building up a reserve of knowledge and technique for future workers to draw on."

COSMOGONY

One of the reasons why one studies mathematics and the sciences is this: to obtain a better understanding of the world in which he finds himself. As the sciences and mathematics have developed, so have developed our views of the cosmos. To primitive man who thought of himself as the center of the universe, to men who with Ptolemy regarded the earth as the center, to men who with Copernicus placed the sun in this strategic position, the cosmos presented a very different view. This view colored many aspects of their thinking. It led to the formulation of a very different philosophy of life. So much so that someone has said "tell me a man's view of the Universe, and I will tell you what sort of man he is." There have been religious upheavals attendant upon man's change in his views of the world about him. In our own day his view is suffering what is perhaps its greatest change. Not only has the sun been displaced from its central position, but in its place nothing has been substituted. We are told that there is no known center; no reference frame in which to orient a path in the cosmos. We have mysterious cosmic rays beating down upon us from an unknown source with unknown effects. Out in an unknown place somewhere, Millikan suspects cosmic radiation may be rebuilding matter—an inverse phenomenon never dreamed of until our time. These are tremendous disturbances in man's view of the cosmos. That there have been no attendant religious disturbances is a conspicuous testimonial to intellectual freedom. The lay world is becoming accustomed to regard almost as commonplace views which former generations held to be impossible in some instances unintelligible. That the world can

achieve this transition complacently is due in large part to the tough intellectual fiber provided by mathematics and the sciences.

SOCIAL IMPLICATION

Einstein asserts that "concern for man himself and his fate must always form the chief interest of all technical endeavors * * * in order that the creations of our minds shall be a blessing and not a curse to mankind." That scientific findings have the potentiality of becoming the latter is the thought of many at this time when modern warfare threatens the very existence of civilization. May not our very scientific endeavors prove a Frankenstein? It has even been suggested that science take a holiday in order to let the rest of the world, particularly the world of good will, catch up. But, as Hill has pointed out, the scientist is after all a human being. Can he know which of his discoveries will be put to harmful ends? Mankind must learn to take the good and the bad together. "It is ironical," says Gregory, "that greater productivity through invention should bring more distress and unemployment rather than an increase in human welfare." Social progress has not kept pace with scientific progress. Russell takes the position that if mankind were rational, his conquest of nature would increase his happiness and well-being. "Only kindness," he says, "can save the world, but even if we knew how to produce kindliness, we should not do so unless we were kindly."

This dilemma, many believe, is caused by our failure to apply to social and economic problems the same intelligent analysis that has been applied to scientific problems. They assert that scientific thinking is definitely on a plane above thinking in other fields—and that this explains the fact that science has outdistanced nonscience. The ideal of thinking is presented in the perfectly welded chains of mathematical proofs. The sciences approximate this norm more closely than do the nonsciences. Social, as well as scientific progress, comes with the finding of truth. The pattern for the search for truth is mathematical thinking.

FAITH

One rarely thinks of faith as an element essential to the scientist. The scientist is by definition one who knows. What need then can he have of faith? Mark Twain says that, "Faith is believing what you know ain't so." Somewhere Hilaire Belloc exclaims, "Oh, one should never, never doubt what no one can be sure about." Does this levity contain some truth? Does not the worker with facts need faith as a sort of whistle to keep up his courage? If he is never really sure, does he not need faith to bolster up this insecurity? Or is it that a calm, pervading faith is one of the necessary tools in the kit of the scientist?

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That the latter is the attitude with which the scientist should approach his task we are assured in the retiring address of President George D. Birkhoff, of the American Association for the Advancement of Science, delivered this past year at the Christmas meeting in Richmond. There one of America's foremost mathematicians spoke to America's scientists of the faith that is his. It is fitting that we here try to catch an overtone of that meeting.

Mr. Birkhoff claimed that whether it is the mathematician dealing with number, or the physicist with matter, the biologist with organism, the psychologist with mind, or the sociologist with social values, there is behind one and all an inherent faith guiding the reasoned superstructure which they create upon intuitional concepts. Whether it is the mathematician's belief in the existence of infinite classes, the physicist's belief in the presence of a discontinuous process at work in the theory of radiation, the biologist's belief in a vitalistic theory of life, the psychologist's belief in a physiological accompaniment to every psychical fact, or the sociologist's belief in societal progress, Birkhoff emphasizes faith as an "heuristically valuable, more general point of view, beyond reason, often in apparent contradiction, which the thinker regards as of supreme importance as he endeavors to give his conclusions the greatest possible scope."

Some think that there is an opprobrium attached to any belief, that belief and science are mutually exclusive. Do these same people believe in the processes of logic? Do they have faith in the rationality of the human mind, in the similarity of the perceptive and reasoning faculties of normal, civilized beings? Is it not in their code that nature is orderly, and that there are spiritual values underlying material facts?

CONCLUSION

In the foregoing we have traced in broad outline the advance in scientific thought from the earliest time down to the present. We have pictured the scientist journeying down this path with his guide, the mathematician. We have noted some of the scenes from certain plateaus and valleys in the path. Continuity, causation, determinism, law, the postulational method, symbolism, prediction, invention, cosmology, social implication, faith, have passed in review. We have endeavored to point out how the guiding hand of the mathematician has aided the traveler along the way. The physical aspects of science, particularly those relative to the structure of matter, have been stressed because they are better known and because of the major importance of matter as "the building blocks" of the universe. There has been no disposition to indulge in propaganda for mathematics. Mathematics needs no "sales talk" to the scientist. It has been rather

an effort to understand its function in the domain of scientific thinking. This relation seems to be much like that of the guide to the mountain climber. Hardly could a guide be better fitted for his task. Bound to the traveler by a philosophical bond they rise or fall together. The assistance is by no means all on one side. Many are the instances in which the problems of the scientist have enriched the theories of the mathematician. Many are the instances in which the theories of the mathematician have aided in the solution of the problems of the scientist. The equations of the mathematician are regarded by many as the only language which nature speaks. Helmholtz expressed this thought in the words, "the final aim of all natural science is to resolve itself into mathematics." Jeans has this in mind in his statement, "all the pictures which science draws of nature, and which alone seem capable of according with observational fact, are mathematical pictures * * * the Universe seems to have been designed by a pure mathematician." Even Galileo back in the beginning of what we are pleased to call modern science said, "Nature's great book is written in mathematical language." Whitehead maintains that the aim of scientific thought is, "to see what is general in what is particular and what is permanent in what is transitory." In this vision science utilizes the general abstraction of mathematics and adopts its theory of invariants. The concept of progressive change is basic in the study of natural phenomena. This same idea is the mud sill of the calculus. "With the calculus as a key," continues Whitehead, "mathematics can be successfully applied to the explanation of the course of nature." When classical physics suffered the impact of the Michelson-Morley experiment it was forced by its own findings to reexamine its foundations. "In this emergency," to quote Dantzig, "it was entirely due to the flexible mental apparatus with which the mathematician supplied them, that the physical sciences have at all survived this drastic revision." Richards asserts that "when we reach the core of physical reality, the truth is presented in mathematical equations." Weyl claims that in the long ago the Pythagoreans held that the world was not "a chaos, but a cosmos harmoniously ordered by invariable mathematical laws." Jeans expresses it in the words, "Nature seems to know the rules of mathematics as the mathematicians have formulated them in their studies without drawing on experience of the outer world."

We come now to the end of tonight's account of this amazing journey of the scientist. In saying farewell to our scientific traveler we hear that insistent injunction from the mouth of his guide, so aptly put by Dantzig, "Read your instruments and obey mathematics; for this is the whole duty of the scientist."

THE ROLE OF SCIENCE IN THE ELECTRICAL INDUSTRY [1]

By M. W. SMITH

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[With 1 plate]

Behind the phenomenal growth of the electrical industry lies an important fact: "The industry has consistently accepted and adapted to its own use the new ideas and developments of science."

The story of the electrical industry is one of growth in giant, breath-taking strides and great technical advances. Turbine-generator units have progressed to the stage where ratings of 100,000 kv.-a. at 3,600 r.p.m. and 300,000 kv.-a. at 1,800 r.p.m. can now be built. Hydraulic generators, the size of which may ultimately be limited by manufacturing facilities because of their large diameters, have exceeded 100,000-kw. rating. Efficiencies of some of the large hydrogen-cooled turbine generators, synchronous condensers, and frequency changers have approached 99 percent in individual units. Transformers have increased to present-day ratings of over 150,000 kv.-a. per bank, and efficiencies of well over 99 percent have been realized. Circuit breakers are capable of interrupting several million kilovolt-amperes—equal to that of the short-circuit capacity of some of the large interconnected systems. Lightning arresters [2] are available with sufficient capacity to handle a direct lightning stroke of over 100,000 amperes and yet limit the voltage to safe values.

Behind this growth, the rate of which has shown no diminution since the birth of the industry, lies a significant, important fact. The industry has consistently accepted and adapted to its own use the new ideas and developments of science. In fact the industry has fostered and encouraged fundamental research to the point that the research laboratory has become an integral part of the industry itself. It also recognizes the value and importance of the scientific accomplishments of the universities and other research institutions, and maintains a close contact with their work.

[1] Reprinted by permission from Electrical Engineering, vol. 59, No. 2, February 1940.

[2] A lightning arrester is an electrical device used to protect electrical equipment from damage when exposed to lightning or other voltages that are higher than that for which the equipment was designed to operate.

Although the industrial laboratory has become the basic element in the electrical industry, the manner by which its fruits are put to practical use is complex. Not only are there many ways by which a new idea is transformed into a practical thing, but also there are many problems in connection with making the fullest use of scientific effort. These ways and these problems merit a closer examination.

EFFICIENT USE OF SCIENCE PRESENTS MANY PROBLEMS

The task of the industry is not only to uncover new principles and make new discoveries, but also to determine which ones can be put to practical, profitable use, and how. It is difficult to recognize the potential value of new discoveries and to determine at an early stage the possibilities of applying them to industrial processes and products.

THE PROBLEM OF TIMING

The rate of application of new ideas is not dependent solely upon the time necessary to conceive and develop them. It is also influenced by the time required for public acceptance. Household refrigeration, the basic principle of which is very old, required a relatively long time for both instrumentalities and public acceptance. Numerous problems had to be solved in the commercial development of such items as suitable refrigerants, sealed compressor shafts or the alternative of hermetically sealed units, systems of proper lubrication that would be effective for a period of years, elimination of noise, quantity-production methods such as those previously developed in the automobile industry, electric-welding methods, and many other items, including even such things as a system of time payments.

During the first two decades of radio the efforts of radio engineers were directed toward developing methods by which radio could be used as a means of private communication. It remained for a new idea, the opposite of this notion, to allow radio to assume its present stature. Public acceptance of radiobroadcasting was almost instantaneous. This case is an exception to the rule that the exploitation of new products and devices usually results in unprofitable operation for prolonged periods.

The course of carrier current[3] also supports this point. In the middle 20's carrier current came into successful use for communica-

[3] Carrier current is a term used to define currents that are superimposed on circuits such as transmission lines which are already carrying power currents. These carrier currents are induced in, and collected from, these circuits by the use of high-frequency transmitting and receiving equipment which is not metallically connected to the circuits over which they are carried. These carrier currents are generally used for communication and control purposes, and this scheme of operation eliminates the necessity of providing parallel telephone or transmission circuits.

tion along transmission lines. Then came a quiet period of several years in its development, followed about 1935 by an intensified activity which shows no signs of any immediate slackening. The need for high-speed relaying of long lines, the development of better tubes, and other changes in the industry spurred engineers to adapt the fundamentals of carrier current to relaying and supervision as well as communication.

Spot welding has been a practical, though limited, industrial tool for many years. However, some 6 or 8 years ago, the idea was conceived of using the ignitron [4] to control exactly the duration of the welding current. Since that time, spot welding has grown enormously both in total use and in diversity of applications. The ignitron, incidentally, was originally developed not with welding in mind but to increase the reliability of mercury-arc rectifiers.

THE PROBLEM OF OBSOLESCENCE

The industrial laboratory poses the inexorable problem of obsolescence. Fortunately the leaders of the electrical industry have taken the far-sighted view that, in order to make sound progress, the seeming ruthlessness of obsolescence must be accepted. Unless one has studied the rates of development and consequently the rates of obsolescence, it is seldom realized how relentless is the march of progress.

A plant that is modern today may be out of date tomorrow. As a matter of fact, the more progressive companies attempt to anticipate obsolescence. Capital expenditures are made on the basis of the time at which the new plant or equipment will be obsolete, not when it is worn out.

The discovery of a new fact in science may completely upset an existing design. Even though the style or performance of a product may not be greatly modified, the practice of the art or process by which it is produced may be radically changed. With the steep rise of welding not long ago, in a few short years the method of constructing most large machines swung from casting to welded fabrication. Neither the appearance nor the performance of the machines was fundamentally altered by this change; the principal motive is economy of time and of construction cost.

It behooves all managements to keep themselves keenly alive to the necessity of meeting changes resulting from progress. Of all competition, there is none quite so ruthless as that which replaces. We all can remember that during the early stages of radiobroadcasting, several plants rapidly grew up for the making of radio headsets.

[4] The ignitron is a special form of the mercury-arc rectifier, and is generally used to convert alternating current to direct current.

The development of the loud-speaker practically ruined this active business. The early sets used vaccuum tubes supplied by direct current, requiring plate and filament batteries. This created a heavy production of dry batteries that was subsequently curtailed by the development of plate-battery eliminators. Later, the development of the copper-oxide rectifier eliminated the use of the storage battery for filaments, and still later, the development of a.-c. tubes so completely changed the design of radio receivers that it rendered many inventories and factory equipments obsolete.

The most recent step in this evolution—and one that shows the cyclic character of many industrial developments—is the battery-operated portable set that has suddenly become so popular. It is additionally significant that although a tube development displaced the early battery set, another development of tubes brings the battery back—the perfection of a tube that operates successfully on 1½ volts.

This last development also shows the rewards from the policy of letting the obsolescence caused by science take its seemingly ruthless course. The new battery-operated radios do not offer new competition for established types of radio sets, but instead simply create or uncover an additional demand for radios. The demand for batteries and for tubes promises to reach an all-time peak.

Similar successive steps of development occurred in illumination. A large kerosene-lamp industry was rendered obsolete, particularly in metropolitan districts, by the coming of the gas mantle. It, in turn, was replaced by the electric lamps. Now a new family of lamps—the gas-discharge lamps, which include sodium-vapor, high-pressure mercury-vapor, and fluorescent units—with efficiencies several times those of incandescent lamps, have demonstrated their practicability. It is still too soon to predict to what extent they will become the universal illuminants, but there is more than a hint that illuminant evolution is not at an end. No one in the industry thinks for a minute that the more efficient light sources presage a decrease in the requirements for energy or equipment. On the contrary, as in the past, this improvement should promote further expansion.

INDUSTRY FINDS MANY BENEFITS FROM ORGANIZED RESEARCH

The industrial laboratory has served the march of electrical progress in many ways. Not the least of these is that it has served to bring the scientist, the design engineer, and the application engineer into closer contact. They now talk the same language and use the same tools. Universities are giving more attention to the training of industrial scientists, and within the last few years, important meetings have been devoted to discussions of the application of physics to industry.

The cooperation of university and industrial scientific effort has also contributed much to the progress of development by bringing scientists of different training closer together on specific problems. For instance, much of the recent progress in the improvement of insulation for electrical apparatus has resulted from the combined efforts of physicists, chemists, and electrical engineers working harmoniously in close-knit groups. For many years, only a limited number of scientists in the universities had shown any interest in dielectrics, particularly solids. The engineer stumbled along rather blindly, and little progress was made until all phases of the problem were coordinated through the industrial laboratory. This relationship not only has served an important function in coordinating the efforts of individuals, but also has exerted a strong influence in bringing together the various departments within an organization as well as outside agencies on problems of mutual interest. A new development for one department is often seen to be of value to another. Thus, research acts as a clearing house for information and stimulates its flow from one department to another.

JOINT RESEARCH BETWEEN MANUFACTURER AND SUPPLIER

Another coordinating function of the industrial laboratory is the cooperative work between electrical manufacturers and the suppliers of raw materials. For many years, electrical manufacturers have carried on cooperative research with manufacturers of steel, carbon brushes, insulating materials, and other raw materials. As a result greatly improved materials have been developed. These in turn enable the electrical manufacturer to build more reliable and more efficient apparatus, which can be extended into new and larger fields of application.

INDUSTRIAL RESEARCH SHORTENS TIME BETWEEN DISCOVERY AND USE

Another important accomplishment of the industrial laboratory has been to effect a marked reduction in the time between the discovery of a new idea and its commercial application. For example, only a few years ago scientists conceived the idea of using as a germicidal agent a certain type of lamp the rays from which are lethal to bacteria. In the last 2 or 3 years the resulting Sterilamp has been put to regular daily use in tenderizing meat, retarding spoilage of foods, killing bacteria on drinking glasses, helping to prevent infection following surgical operations, and many other important tasks.

Even today, however, special attention must be given to this phase of the problem: After the research work has been completed and the theory or principle of operation has been verified, there still

remains the decision as to the commercial possibilities of the new device or product. Usually sufficient information is not available at this stage on whch to base an intelligent decision. Information as to probable costs (including equipment investment), processes, production methods, market analyses, and distribution methods must be obtained before a decision to manufacture and sell can be made. This requires that the new product be carried through some preliminary stage of development, where a study of these factors is made. Usually this takes the form of some kind of pilot-plant activity under the direction of a special experimental or development group that has the responsibility of carrying new products through this incubation stage following the completion of research work. This form of development is particularly conspicuous in the chemical industry.

PATENT SYSTEM STIMULATES NEW DEVELOPMENTS

Our patent system has had a stimulating influence on industrial research and developments in the electrical industry that should not be overlooked. It costs money to develop and exploit inventions. The protection afforded by patents provides an incentive to develop new things under conditions such that they may be exploited long enough to become established. Quite often a strong urge toward a particular development seems to become manifest and inventive effort starts simultaneously in many places. This seeming chaos that theorists would like to control from some central throne eventually turns into true cooperative effort through the practical necessity for cross-licensing of patents before a useful product can be obtained. Television is a present-day example. Patents themselves are published and the protection afforded does away with the necessity for secrecy. The new progress that has been made impinges upon other minds, thereby starting new chains of ideas that result in coordinated group effort leading to rapid progress.

Without the protection provided by patents, capital would be reluctant to venture into new fields. Industrial research would become secretive, and because of the resulting lack of cooperation and coordinated group effort, our progress in technical accomplishments and standards of living would be seriously retarded.

In the light of these advantages, many times verified by experience, it is disturbing to observe the tendency in some political circles to propose legislation that would destroy these values and place serious limitations on individual right. Even the uncertainties surrounding such proposals create a lack of confidence, tending to retard initiative and technical progress. This same condition exists to a large extent throughout the industry, and particularly in the public-utility

field where political threats and limitations have seriously curtailed expansion and thus retarded the use of scientific developments directly in the generation and distribution of electricity.

ELECTRICAL INDUSTRY DRAWS FROM ALL BASIC SCIENCES

Contributions to the development and progress of the electrical industry have come from practically every branch of the basic sciences. This is not surprising when we consider the large variety of materials used in the manufacture of electrical equipment.

Metallurgy.—Improvement in electrical apparatus is largely dependent on the improvement made in the properties of the materials used. This applies to both physical and chemical properties of various kinds. The limitations in physical properties of materials are most likely to be encountered in high-speed rotating machinery such as steam turbines, where centrifugal and steam forces are likely to be large under conditions of high temperature, which in turn tends to lower permissible stress limits.

Research work done in recent years by both electrical and steel manufacturers to determine and improve the fatigue, creep,[5] corrosion, and other physical properties of various alloy steels used in highly stressed machines has resulted in such marked advances in design that output ratings have been more than doubled at the highest operating speed in less than 5 years.

The electrical industry has also called on the metallurgist for new and improved magnetic steels and alloys. Magnetic steel, particularly electrical sheet steel, has been a subject of continued research by both electrical and steel manufacturers. This has involved studies of molecular and grain structures as well as of chemical compositions and purity. This work has resulted in a steady decrease in iron losses[6] in the cores of transformers and machines of such magnitude that they have been reduced by more than half in the last 20 years, with a saving to the industry of millions of dollars annually.

Until recently, the improvement in electrical sheet steel was confined largely to iron losses. Practically no improvement in perme-

[5] When a load or strain is applied to a structural member such as a steel bar, the bar elongates or stretches proportional to the load applied up to the elastic limit of the material. For most practical applications, this elongation for a given stress is presumed to remain fixed or constant. Actually, most materials will continue to elongate at a very slow rate (in some cases over a period of years), even though the stress remains constant at a value below its elastic limit. This property or characteristic of materials to slowly elongate on a constant stress with time is commonly referred to as "creep."

[6] In the iron cores of electrical devices, such as generators, motors, and transformers, which either generate or receive alternating current, the magnetic flux is subject to reversal at the same frequency as the generated or applied alternating current. This reversal of magnetism produces a molecular friction loss inside the iron core which results in an energy loss that appears in the form of heat. This energy loss is commonly referred to as "iron loss."

ability had been accomplished. As a result of recent research and development we now have a magnetic steel that has not only lower iron loss but also much better permeability.

New alloys are sometimes discovered and developed as byproducts of other research work. In the electrical industry, the need for new alloys with special characteristics often arises in connection with new electrical developments. It is therefore often necessary to develop special alloys to meet limitations encountered in electrical developments, particularly when the volume required is too small to be attractive to alloy manufacturers. For example, a recently developed alloy containing only a few percent iron, is stronger at 1,100° F. than any low-carbon steel at room temperature. It creeps very little. It survives a 6,000-hour creep test at 1,000° F. that causes cast carbon-molybdenum steel to fail and high-strength nickel-chromium steel to creep 100 times as much. As an amazing demonstration of how it retains its elastic properties when hot, a bar of steel and one of this alloy were heated to 1,100° F. When struck with a hammer, the steel bar responded with a dull thud; the alloy with a clear, bell-like tone.

Chemistry.—The application of chemistry to the electrical industry has been almost unlimited. Chemists have been called on principally to produce new and improved insulating materials, compounds, varnishes, oils, etc. There have been many other developments, however. For example, a fireproof chlorinated compound has been developed to replace transformer oil in applications where fire hazards exist. Many fireproof liquids have been made available, but a great amount of research and development work has been required in recent years to obtain a material that also had satisfactory electrical properties such as high dielectric strength, low power factor, and viscosities comparable with transformer oil, particularly at low temperature.

Physics.—The foundation of the electrical industry is supported to a large extent on the laws of physics. Some of the most important scientific discoveries and applications therefore have come from this field. The discovery of electromagnetism, the electron, and the X-ray are outstanding examples. From researches on the mechanics of the ion came the principle of circuit interruption by deionization that has been applied to a whole family of interrupting devices from the giant circuit breakers that handle millions of kilovolt-amperes down to the new practical circuit breakers for the home that are little larger than a wall switch. In the field of electronics, numerous electrical developments of far-reaching importance have been based on these and similar discoveries.

Mathematics.—Probably no other industry rests on such a precise mathematical basis as the electrical industry. From its very begin-

ning its every step in the design, construction, and operation of electrical apparatus has been guided by computation. In fact, the electrical engineer has invented several mathematical tools to serve his purposes, such as the complex quantity and symmetrical components. He has even placed his mathematics on a mechanical basis, such as that amazing creation, the calculating board.

Pure mathematical concepts have given birth to many electrical devices. Particularly has this been true of relays for the protection of transmission lines and terminal equipment. A conspicuous recent example is a new, simplified pilot-wire relay that greatly extends the practical field of this type of relaying. This relay was conceived directly from the mathematical conception of positive, negative, and zero-sequence components of alternating currents.

AS TO THE FUTURE

We know so little about nature's basic underlying principles that it is incredible that anyone should think that our knowledge of natural laws is anything but exceedingly small when compared with the vast amount that is listed in the unknown column. This alone should be encouraging, for if we can accomplish all that we have with such a poor understanding, it is reasonable to expect vastly better results as we obtain more basic knowledge.

While our human limitations may prevent us from seeing very far into the future, present developments give us some idea of future trends and in what fields expansions are likely to occur.

In the processing industries, electricity will probably assume an increasingly important role in the way of metering, regulating, and controlling numerous phases of new as well as existing processes. Recent improvements in electric furnaces and their controls, including the control of the atmosphere inside of the furnace as well, indicate various possibilities in this field. For instance, heat treatment of steel sheets for automobiles by continuous processes in less than 15 minutes has been accomplished. In the presence of highly purified atmospheres, various steels and alloys can now be bright-annealed. In controlled-atmosphere furnaces, dies can be heat-treated without oxidation or carburization, thus eliminating subsequent grinding.

In the broad field of air conditioning, electricity will play an important part, not only in applications requiring power but in the processing and treatment of the air itself. Electrical means are now available for cleaning and sterilizing air. These new aids in air conditioning, coupled with the available services of heating, cooling, and humidity control, make it possible to improve man's living conditions so profoundly that he may live in a clean spring or fall atmosphere all the year around in any locality.

Lightningproof electrical systems were but the dreams of engineers a few years ago. They are still not a reality, but the day is coming when they will be. Much has been done in this direction; more is yet to be done. The recent development of a device for recording natural lightning strokes that is relatively inexpensive and simple, so that dozens of them can be installed over wide areas, will be of tremendous assistance in collecting that quantity of statistical information about lightning necessary for the construction of protective devices and self-protecting apparatus. We now have reason to believe that in the not too distant future lightning, once the great disturber of electrical systems, will be eliminated as a hazard to power continuity.

Vast new vistas are being opened by high-frequency electric energy. High frequencies, which broadly include everything beyond 60 cycles, are already being used for numerous tasks of melting, heat-treating, and drying. Packaged raw materials are being dried without opening the containers; bearing surfaces of finished engine crankshafts are being given additional hardness by localized heating induced by high-frequency currents. With the rapid developments in high-frequency generators, both of the rotating and electron tube types, it is not inconceivable that all gasoline and Diesel engines, machine tools, and other machines will be treated by high-frequency when assembled or partially assembled to harden the wearing surfaces.

The great field of electronics, which is now best known in radio, television, and communication, can be expected to find a greater number of future applications in the electrical industry, particularly in those fields having to do with automatic machine operations, inspection of materials and safety methods. Recent progress in the development of larger and more reliable metal-tank tubes indicates that electronics may also be expected to play an increasingly important part in electric-power distribution, both in transformations and control.

When it is considered that the power consumption in many small homes today is from 3 to 10 times the national average, due to the increasing acceptance of electric ranges, water heaters, forced air circulation, high lighting levels, and other conveniences, we can expect domestic power consumption to double in a reasonable time. This indicates the need for an improved low-voltage distribution system as well as rewiring of homes.

Agriculture is another field that has scarcely been touched by the electrical industry. In addition to the usual applications of power and light, there appear to be many possibilities of applying treatments and radiations for the stimulation of plant growth and control of insects that now infest grains, plants, and seeds.

Present researches in nuclear physics in many institutions may result in obtaining information that will be just as extensive in its influence on the developments in the electrical industry as was the discovery of the electron. The production of radioactive substances, through the disintegration of the atom may provide a very useful tool. Naturally, one thinks of using these radiations instead of the X-ray for radiography or for radium in the treatment of disease. While they no doubt will be used to some extent for such purposes, the possibility of using these radiations as a means of studying certain atomic reactions and structures may be even more useful. For instance, by the use of electrical-detection methods, it appears feasible to follow the migration of radioactive atoms through a metal during heat-treating processes. Similarly, it is possible to trace the movement of radioactive substances through a plant or the human body and thus learn more about how and where these substances are assimilated. In contrast to radium, most of these artificial radioactive substances have such a short life that no permanent harm is done to the human system.

The present methods of generating electric power are so well established that we are inclined to accept them as permanent. Gradual improvements in present methods have reduced the amount of coal used per kilowatt-hour to approximately one-fourth that required 20 years ago. While this improvement is indicative of real progress in steam-power generation, it is still small when compared with the theoretically possible energy that could be gotten from a highly efficient method of energy conversion.

With an increasing knowledge of the fundamental properties of matter and a better understanding of the conduction of electricity in gases, recent calculations and experimental work indicate that it may be possible to use the electromagnetic properties of the rapidly moving ionized products of combustion of certain fuels in conjunction with some suitable electrical transforming device as a means of generating electric energy. A practical development of this idea, which at least appears to be a possibility at the present time, would result in the use of static electrical devices extracting power from the kinetic energy of the gases of combustion without the intervention of rotating electrical machinery.

Although these and many other prospective developments that might be mentioned are indefinite and difficult to evaluate, we can look forward with the expectation that the electrical industry will continue to grow under the stimulation and impetus of new scientific discoveries and advances.

PLATE 1



RESEARCH STUDIES OF VIBRATION IN LARGE STEAM TURBINE BLADES.

THE NEW SYNTHETIC TEXTILE FIBERS[1]

By HERBERT R. MAUERSBERGER
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We are living in a fast and progressive age as far as textiles are concerned, recently referred to as a "fiber revolution." The old natural fibers do not any longer limit the ability of the textile industry to create and supply new fabrics of unusual character, beauty, and usefulness. These new developments mark an advance in fiber technology, which must be examined and evaluated with the greatest care by all who wish to keep up-to-date. They create both opportunities and hazards for the progressive textile manufacturer—opportunities for those awake to the possibilities they offer of meeting our human needs more fully; hazards for the ultraconservatives, who let progress pass by. To the technical man, they are fascinating and worthy of careful examination and study.

In my investigation of these new synthetic fibers I have not included the cellulosic filaments and fibers, such as rayon or modified rayons. I believe that the word synthetic has never been applicable to rayon in its various textile forms. True synthesis would involve the union of chemical elements to form the basic substances from which a textile fiber is obtained. This stage has not as yet been accomplished, but the new man-made fibers I shall discuss come very close to this ideal.

My information has been obtained from sources I believe authentic, such as patents, chemical abstracts, newspapers, both local and foreign technical publications as well as private correspondence with the companies directly involved.

In discussing them with you, I will take them up in the order of their present relative importance. I will also include a few in which research work has been practically completed but which have not been marketed as yet in this country for economic or other reasons, which I shall state. In each case I will state the origin, comparative

[1] Paper presented before American Society for Testing Materials, Papers Session, October 17, 1940. Reprinted by permission from Rayon Textile Monthly, November and December 1940.

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properties as far as they could be ascertained, and their present or past uses.

The importance of these new synthetic fibers may be more fully understood when it is considered that the supply of some of our natural fibers may be cut off or prices become prohibitive. At a recent technologists' meeting, the Army, Navy, and Air Force have taken serious recognition of this and are making tests on substitution for silk and wool in particular.

Through the courtesy of Mr. von Bergen, Director of Research Laboratories of Forstmann Woolen Co., prints of a number of new synthetic fibers, both in longitudinal and cross section, are found in the new Textile Fiber Atlas to be published soon.

NYLON

Nylon is the generic name chosen by the du Pont Co. for "a man-made proteinlike chemical product, which may be formed into fibers, bristles, filaments and sheets, and when drawn is characterized by extreme toughness, elasticity and strength," to quote from the company's statements. This means that it has to some degree the same chemical composition as the proteins, of which silk, hair, and wool are common textile examples. The term "nylon" does not refer to any particular chemical form of the polyamide any more than glass refers to any particular form or item of glass.

It is an outgrowth of considerable research begun by du Pont in 1928 and its success was announced by the company on October 27, 1938. To explain how it was conceived and how it is made today would be a paper in itself. I shall confine myself only to the textile aspect and its various desirable properties. While nylon is commonly stated to be made from "coal, air, and water," much more is involved. To the technical man, it can be made from a dibasic acid derived from phenol and a diamine, likewise derived from phenol. Oxygen from the air is needed in the dibasic acid, and ammonia is used in making the diamine. Since phenol is commonly derived from bituminous coal and since ammonia is made synthetically by causing the hydrogen from water to unite with nitrogen from the air, it follows that this particular nylon is derivable from coal, air, and water.

In regard to its physical and chemical properties, it must be said that nylon is the first synthetic textile fiber that has reached practical use and thereby has proved definitely that it is possible to make textile fibers synthetically and with raw materials other than cellulose. Nylon has a crystalline polyamide structure, can be drawn cold, and is exceedingly strong and elastic. This is attributed to

the orientation of molecules in the drawing process, which can be altered to suit any particular condition or demand. It is the properties of the yarn resulting from this control of molecular arrangement which caused the company to introduce it in the manufacture of fine hosiery. Nylon is also extremely tough, standing long wear and abuse, making it ideal for the bristles in tooth and hair brushes, fishing leaders and the like. It is resistant to abrasion. Its resistance to heat is good, i.e., its melting point is around 480° F., which is above the temperature normally used in ironing fabrics. Nylon does not burn or blaze or propagate a flame. It merely melts. Hence, no fire hazards are involved in its use. It is not injured by water or any liquid commonly used in the home. It is attacked by phenol (carbolic acid) and certain mineral acids normally found in the laboratory only. It is readily wet out by water, but absorbs much less water than common textile materials. Hence, nylon articles dry extremely rapidly and are just as strong wet as when dry. Hot water and saturated steam impart a substantially "permanent set" to nylon yarn and fabricated materials, which serves to retain its shape. Of course, nylon can be made waterproof or water-repellent by customary treatments.

Nylon, like all ordinary textile fibers, is subject to injury by ordinary light. It is claimed to be at least equally as resistant to indoor and outdoor light as corresponding unweighted silk fabrics. It can be stored in the absence of light for long periods without injury. Nylon is absolutely proof against attack by moths, fungi, and bacteria. Nylon has good insulating properties and high abrasion resistance. Its refractive index in the textile form is 1.53 to 1.57 Nylon is doubly refractive and when examined between crossed Nicol prisms, all colors of the rainbow appear.

Of its present 4,000,000-pound production, 90 percent goes into the manufacture of fine, full-fashioned women's hosiery. It has found application in the manufacture of sewing thread known as "Neophil." It is also used for corset fabrics and for shroud lines for parachutes, and is now being developed for the parachute fabric itself. As a monofilament and bristle, it is used in "Exton" and "Miracle Tuft" tooth brushes and hair brushes; also as surgical sutures.

While nylon is produced at Seaford, Del., with a capacity of 8,000,000 pounds, another plant is being started at Martinsville, Va., which will bring the production to 16,000,000 pounds by the spring of 1942.

Much of this information is already available to technicians, scientific workers, and textile experts. It is merely repeated for the sake of A. S. T. M. records and also as a summary for you. Nylon serves as an excellent example of what can be done to construct and

manufacture textile filaments and fibers to suit specified needs and modern demands.

VINYON

This is probably the most promising new synthetic textile fiber. While already hinted at by Dr. Robert Hooke in 1664, and by René Reaumur, the production of a suitable and practical textile fiber from gums and resins did not become a reality until synthetic resins were made.

Vinyon was originally made by Carbide & Carbon Chemicals Corporation and described in a United States patent, No. 2,161,766, granted to Rugeley, Field, Jr., and Conlon in 1937. Later in 1939 the American Viscose Corporation took up the manufacture of the filament yarn and fiber.

Vinyon is the result of extensive research on vinyl polymers, specifically a copolymer of vinyl chloride and vinyl acetate produced by polymerization rather than by condensation. The raw polymer in the form of a white fluffy powder is dispersed in acetone and a dope is obtained containing 23 percent of the copolymer by weight. After filtering and deaerating, this solution is spun the same as acetate and coagulated by the dry- or warm-air process. After conditioning on take-up bobbins the yarn is wet-twisted to 6 turns per inch, whereupon it is given a stretch of over 100 percent of its original length, giving the yarn its high tensile strength and true elasticity. It is also produced in the partially stretched condition for certain purposes at a lower price. They are now produced in 40, 60, 80, 120 deniers and up.

Delustering is done by incorporation of pigments and a new process has been found to produce a mild delusterization directly in spinning. The yarn has no abrasive action and, owing to its high tensile strength of 1–4 grams per denier and elongation from 18–120 percent, will stand abrasion well. The tensile strength is the same when wet or dry. Dyes are rapidly being found so that it can now be colored in a wide variety of shades.

These unusual properties have caused the yarn to be employed for many industrial fabrics, such as filter cloths, pressed felts, sewing threads and twines of various types, chemical workers' clothing, sail and tarpaulin fabrics, fish nets, parachute cords, chemical-resistant hose, noninflammable fabrics, awnings, curtains, and upholstery. Vinyon staple fiber has been mixed with cotton, wool, and rayon, and fabrics made from it will retain their pressed shape, fold, or crease very well. Maximum concentrations of mineral acids, caustics, alkalies, bleaching agents do not affect vinyon. It has no affinity for moisture, does not support bacteria and virus growth, and is not subject to damp rot, mold, or mildew.

It is truly a synthetic fiber, of truly amazing properties and not like any natural fiber—another excellent example of what can be done in creating fibers of special character to meet special needs.

Modifications and further experimentation in this category of synthetic textile fibers have produced other very interesting and valuable materials in Europe known as Pe-Ce fiber, Synthofil, Igelite, and Permalon. The latter is a vinyldene chloride derivative which the producer, The Dow Chemical Co., calls Saran. According to Pierce Plastics, Inc., of Bay City, Mich., they take this white powder and exude it after heating through a die. When the filament issues from its die it is hot, and thence is passed through a tank of water. It is then taken to a stretching device, where the size of the threads is controlled and at the same time acquires a tensile strength of 40,000–50,000 pounds per square inch. When the company first started, it made Permalon threads solely for fishing-leader material. They now make small tubing, which is used for catheters in hospitals. A number of textile concerns are now making a narrow fabric and upholstery seat fabrics of Permalon threads—a very remarkable and interesting development of considerable importance.

Dow Chemical has also made experiments with ethyl cellulose derivatives, known as Etho-raon, Ethocel, and Ethylfil. I am informed that Dow Chemical is not ready to disclose any details, but has stated that these materials are very similar to cellulose acetate rayon. It was first made known at the National Farm Chemurgic Council in Detroit. More information on these new textile fibers may be available later.

CASEIN FIBERS AND FILAMENTS

Probably the most extensive and costly research was done on the possibility of producing synthetic textile filaments and fibers from milk casein, first mentioned by Todtenhaupt in 1904. He dissolved casein, which is the coagulable portion of milk, in an alkaline fluid and then allowed the solution to fall, or pressed it in the form of thin threads, into an acid bath. Later the spinning solution was dissolved in zinc chloride, spun and insolubilized in a formaldehyde solution which made the filaments softer and more pliable. The principal objections and early difficulties were the proneness to swell, soften, and stick together at normal temperatures during dyeing. Many experiments were necessary to overcome this and finally resulted in the Ferretti process of Italy in 1935, which has produced a satisfactory commercial product known as Lanital.

In Ferretti's process the casein is dissolved in dilute aqueous alkali, allowed to stand 2 to 3 days until the solution becomes thick and viscous. A solvent is gradually added to the desired volume and viscosity, then spun, rendered insoluble, and deacidified. This fiber

has shown closer resemblance to wool than any other synthetic fiber yet produced. This fiber was imported into this country as Lanital until Italy entered the war.

Owing to certain weaknesses in the casein fibers, particularly tensile strength in dyeing, attempts have been made to mix viscose and casein together. Such products as Railan and Cisalfa are the result of such experiments. Further, casein has been mixed with Latex and glue with some success in fibers known as Tiolan (German) and Lactofil (Dutch).

In this country Whittier & Gould in their United States patent No. 2140274, of December 13, 1938, and later No. 2204535 in June 1940, offered a process of making casein fiber and assigned the patents for public use.

Recently in this country a new synthetic staple fiber has been announced by F. C. Atwood, president of the Atlantic Research Associates of Boston, under the trade name of Aralac. It was announced at the National Farm Chemurgic Conference in March 1940, at Detroit. This casein material is made in natural or opaque form, or in a delustered condition; also in a softened condition to simulate the softness of high-quality wool, as well as in an unsoftened condition, possessing a scroop. It is made in less than 20 microns and over 30 microns to match the thickness of every grade of wool. It is now being produced commercially by the Aratex Division plant of the National Dairy Products Corporation, at Bristol, R. I.

The present physical and chemical properties are about the same as Lanital, reported on by von Bergen. It has a high affinity for all wool dyes. Its dry strength is about one-half that of wool and its wet strength is about one-fifth that of wool. Compared to viscose rayon it has about 10–20 percent less strength. Of course, lack of strength is not always a drawback to its introduction, as was the case with rayon.

The longitudinal structure of Aralac is more or less smooth and shows no pronounced indentations or striations like rayon, but its surface is peculiarly "rippled," the only word I can find to describe it. Its cross section is nearly circular and highly uniform. The contour shows hardly any deviation from a smooth circle. Its differentiation from soybean and Lanital is not easy, because of its close chemical composition.

The price of Aralac is now from 40 to 55 cents per pound. Its principal use at present is in the felt-hat industry, as an admixture with wool and rabbit hair. It is claimed that hats and hat bodies containing up to 50 percent of Aralac are already on the market. Experiments in other woolen fabrics and admixtures are now in progress and all uses will consume almost a million pounds in the first year of its existence.

According to an announcement last week the National Dairy Products Corporation has a new casein fiber known as R–53 [2] (finer than Aralac), which is furnished to the Hat Corporation's three plants in long continuous strands of 15,000 filaments each. These are cut to ¾-inch staple lengths and blended with natural fur in proportions of 10–15 percent casein fiber to 90–85 percent rabbit hair. They claim men's hats made from this blend are the equal of orthodox felt hats in appearance, feel, resistance to wear and crushing, and superior in color fastness.

SOYBEAN FILAMENTS AND FIBERS

While the major part of research work in soybean has been in connection with the preparation of plastics, foods, paints, oils, and so forth, some work has been done to utilize the protein meal or pulp after the oil has been extracted. The work on the casein pulp has been a side study, rather than a direct study on the part of chemists.

Heberlein & Co., back in 1929, submitted the extracted protein from soybean to a swelling operation with water under pressure and heat or a dilute acid with simultaneous treatment with phenols, after which the filaments are formed by extrusion in the usual manner.

In this country, the first announcement of research work on the production of a synthetic textile fiber from soybean pulp came with the opening of the World's Fair in 1939. A part of the Ford exhibit was devoted to its manufacture. The Dearborn Laboratories of the Ford Motor Co. had been working since 1937 on the idea of producing a synthetic textile fiber that would simulate wool very closely. From 20,000 acres of soybeans under cultivation, they had been using the soybean oil for paints and the meal for plastics.

The process used is about as follows: After the soybean is crushed under pressure and the oil extracted with hexane it is passed through a weakly alkaline solvent, which extracts the protein. The soybean meal is exceptionally rich in protein value—as high as 50 percent. The protein is then combined with various chemicals and/or dyestuffs in a secret process and made into a viscous solution. It is then forced through a spinnerette and coagulated into filaments in a bath containing sulfuric acid, formaldehyde, and sodium chloride or aluminum sulfate. A formaldehyde solution is used to set the filaments during the winding process. They are bleached and dyed, if desired,

[2] R–53 is the laboratory name used for this new fiber by the Hat Corporation of America during the present experimental state of its use. The R stands for research, and the number indicates that this was the fifty-third fiber tested by the company in the course of a 20-year search for a fiber that could be used in making top-quality felt hats. R–53, as used by the Hat Corporation, cannot be regarded as the same as Aralac, because while Aralac rovings are the original raw material from which the company produces R–53, much additional processing is necessary before the fiber is ready for hat making. It must be specially combed to remove noils and knots, and it must be cut to the proper staple length for blending with rabbit fur.

and are then ready for commercial use. The filaments are also cut to produce a staple fiber. The skeins have the consistency and texture of silk and wool, which are our present protein fibers. Ford officials have informed me that Henry Ford himself has shown considerable personal interest in these experiments. The yarn has been woven and knitted into goods and the company considers its suitability for auto upholstery definitely satisfactory and practical. Later, the Glidden Co. at Chicago set up a pilot plant for experimental purposes of fiber production for the textile trade.

The physical and chemical properties of textile fiber produced from soybean are particularly interesting. I submitted a sample of the product to Mr. von Bergen, of the Forstmann Woolen Co., late in 1939. He reported that it closely resembled Lanital in color, luster, touch, and crimp. Its tensile strength was 0.94 gram per denier dry and 0.26 gram per denier wet. The elongation of the filaments was 112 percent dry and 47 percent wet. This means that soybean fiber is about four times weaker than wool when dry and approximately eight times weaker than wool when wet.

The fineness and diameter of the soybean fiber is exceptionally uniform, approaching nylon in this respect. The fibers are more or less smooth with fine dots and streaks or short striations, presumably caused by air bubbles. Similar to protein fibers, soybean fiber does not burn, but chars and produces the same odor as wool, which is like burned feathers. He found traces of sulfur present and yellowish-brown alkali fumes issue when it is heated in a test tube. The fiber shows a high affinity for acid colors with no visible change in the fiber itself. For identification purposes Mr. von Bergen suggests a sulfur-content test to distinguish it from Lanital, if this is ever necessary. Water does not wet soybean fiber as readily as it does casein fiber and wool. Its specific gravity is 1.31. Recent samples are more resistant to carbonizing and to boiling in dilute acids and alkalies.

Hence, the only deficiency is its tensile strength; the filaments and fibers otherwise show remarkable qualities. I am informed that in more recent samples from Ford and Glidden the strength had been improved. Development work on upholstery fabrics has progressed satisfactorily and it looks as if the soybean fiber will soon be a commercially practical textile fiber, ready for the textile trade to use. It is now used in hat felts, suitings, upholstery fabrics, etc. A commercial plant for the production of this fiber at the rate of about 1,000 pounds per day is now planned.

FIBERS FROM CORN

A protein fiber can be obtained from corn meal, which is a corn proteid, often called zein or maisin. It has received considerable

prominence since a patent was granted in May 1939 to Corn Products Refining Co., of Argo, Ill. Zein is obtained from corn and is soluble in 75 percent alcohol, phenol, mixed solvents such as alcohol and toluol, alcohol and xylene, and others. The zein, according to Swallen, of Corn Products Refining Co., is dissolved in aqueous alcohol containing a proportion of formaldehyde, which is extruded into an aqueous coagulating medium and the withdrawn filaments subjected to a current of air heated to not above 100° C., skeined, then baked at 60°–90° C. for 8–10 hours. Up to the present time there have been no difficulties in spinning zein filaments, but the product obtained, when sufficiently insoluble in water, has been deficient in elasticity, resiliency, and tensile strength in the dry and wet condition. They can be dyed. Latest reports from Corn Products are that the work on it has been suspended but may be revived at a later date.

FIBROIN FILAMENTS

The idea of obtaining a merchantable fiber from fibroin, a proteid substance and the chief ingredient of raw silk, is in itself not new. It is composed mainly of two constituents—probably proteins—which comprise chemical combinations of alanine and glycocoll, with some tyrosine. The problem for a long time was to find solvents for this substance, which could be obtained from silk waste, old silk stockings, and silk threads.

The Japanese did considerable work in this field and samples of some yarns, then termed "regenerated silk," came to this country in 1937. Samples from Max Baker were analyzed and investigation showed that a patent and process had been devised in this country in 1923 by Abraham Furman. The patent was assigned to Corticelli Silk Co., of New London, on May 13, 1924. The company tried the process out and produced a 75-denier yarn on a small scale from cocoon waste and other raw and dyed silk noils and waste. The procedure in brief was as follows: The silk waste was cut into very short lengths, boiled off twice, hydroextracted and dissolved in a chemical solution, probably copper or nickel sulfate. The solution was then forced through filters and piped to storage tanks. It was then deaerated and spun on spinnerettes, similar to rayon, with refrigeration, and coagulated into an acid bath. Bleaching was not necessary and the yarn was washed and finished in skeins. The lack of sufficient strength and elasticity finally caused the Thames Artificial Silk Co. and the Corticelli Co. to discard the process. The Japanese samples, while a little better in strength, did not satisfy textile requirements. Many other investigators, such as Galibert, Hoshino, Millar, Lance, and others, are still trying to perfect this method, but so far none has succeeded or undertaken commercial production anywhere.

This is merely an instance of how many efforts have been made and what types of processes have fallen by the wayside. This does not mean that they are impractical or that under favorable conditions they would not be revived.

GLASS FIBERS AND FILAMENTS

Fiberglas (or glass fibers) has been lifted out of the category of curiosities, and is now a textile raw material, with many potential applications. It is being produced by two processes—the continuous-filament process and the staple-fiber method—by Owens-Corning Fiber Glas Corporation. In its manufacture glass marbles are fed into an electrically heated furnace, which has a trough or V-shaped bushing made of metals of a higher melting point than glass. In the continuous process, molten glass, entering the wide top end of the bushing, is "drawn" downward by gravity, the glass emerging from 102 tiny holes in the bottom of the bushing. The filaments, averaging 0.00017 to 0.00020 inch in diameter, are combined to make one strand measuring 0.024 inch in diameter for winding on bobbins. A number of strands can be plied together to produce a yarn of any size.

In the staple process, the molten marbles are forced downward through holes of the same type as in the continuous process, but, instead of being "drawn," they are blown downward by steam under high pressure. Passing through a burst of flame to eliminate moisture, the fibers, averaging 8 to 15 inches in length, gather upon, and are drawn from, a revolving drum. The accumulation of "sliver" follows grooved wheels to be wound on revolving spools. The subsequent spinning operation is carried out on regular textile machinery.

Spun yarns have been made as fine as 100s cotton count. The yarn is put up on beams, cones, tubes, bobbins, and spools, as desired. The physical and chemical properties of glass filaments and fibers are very interesting. The fibers are produced in various colors which are not affected by heat, light, or weather. The fibers are solid, circular in cross sections, and smooth. Fiberglas is fireproof, resistant to acids (except hydrofluoric and phosphoric), weatherproof, and mildewproof. Good dialectric properties and good thermal-insulating characteristics are very pronounced. Glass fiber is attacked by strong or hot solutions of caustic soda.

Fiberglas has a high tensile strength which can be varied by chang ing the glass formula. In general, finer yarns have a greater tensile strength than coarser yarns of the same size. The tensile strength and elongation of the basic 102-filament fiberglas yarn are as follows: Tensile strength, 6.3 grams per denier; elongation, 1 to 2 percent.

The strength expressed in grams per denier of yarns spun from the staple fiber type is somewhat lower and elongation is higher, 2½ to 4

percent. The fibers lose strength when abraded and hence, unless they are protected by a flexible coating, are not suitable for applications involving severe bending or creasing. While the fibers themselves are waterproof, fabrics woven from them are more susceptible to mechanical damage when wet than when dry. Resistance of yarns and fabrics to abrasion has been improved considerably since fiberglas was first introduced, and further progress along that line is expected. At temperatures above 600° F. there is a loss in tensile strength, and at 1,500° to 1,600° F. the fibers start to soften or melt. Fiberglas yarns are approximately two to two and a half times as heavy as cotton yarns of the same diameter.

Fiberglas yarns can be woven, braided, or knitted on the usual types of textile equipment. During manufacture a small amount of lubricant is added to the yarn. Special formulas for warp sizing have been worked out. Fiberglas cannot be dyed satisfactorily by any of the usual processes. Some experimental work has been carried out on printing fabrics with lacquer colors.

For the present, fiberglas textiles have been confined to industrial and decorative purposes. Some knitted fabrics have been produced experimentally. Aside from shoe fabrics, no attempt has been made commercially to manufacture fabrics for wearing apparel. Among the more important industrial applications are filter fabrics; yarns, braids, tapes, and other materials for electrical insulation purposes; anode bags used in the electroplating industry; wicking for oil stoves and lamps; pump diaphragms, and belts for resisting high temperature, fumes, and acids. Draperies made from fiberglas are now on the market in a wide range of designs and colors. Among other potential household uses are tablecloths, bedspreads, curtains, upholstery, wall coverings, and awnings. Still other applications are rope, twine, and sewing thread for sewing glass textiles.

FILAMENTS AND FIBERS FROM CHITIN

Chitin was discovered in 1811 by Braconnot and is a polysaccharide containing nitrogen, present in the cell walls of fungi and the skeletal structure of such invertebrates as crabs, lobsters and shrimps. Like cellulose it may be acetated, but has little resemblance to cellulose and is quite different from fibroin. Rigby in his United States patents deacetylated chitin in 1936, and the product as well as many of its salts may be used for the manufacture of films and filaments. He has used a 3-percent aqueous solution of medium viscosity deacetylated chitin acetate for films, filaments, and for cementing paper sheets, the product being insolubilized by exposure to ammonia fumes.

Kunike, of Germany, in 1926 found that purified chitin is soluble in acids, from which the filaments can be spun wet or dry. It has a round or heart-shaped cross section and its tensile strength is 35 kilograms per square millimeter as against 25 kilograms per square millimeter of cellulosic silk. The pale lustrous filaments resemble acetate rayon and real silk. He claims that the production of textiles from chitin offers no commercial difficulties.

Thor and Henderson, of Visking Corporation of Chicago, Ill., have described the production of filaments from regenerated chitin products. The purified chitin in a modified process is xanthated and filaments are obtained by treating it with an alkali and then with carbon bisulfide, filtering, deaerating, and extruding through minute orifices into a setting bath. The films obtained from regenerated chitin resemble those of regenerated cellulose, but differ from the latter in their affinity for dyestuffs. Its dry tensile strength is somewhat better than regenerated cellulose, but its wet strength is much lower. The only drawback to its commercial introduction is the insufficient supply of chitin, I understand.

GELATIN SILKS

The earliest attempt to produce a commercial textile fiber of a gelatin base was Vandura silk by Adam Miller of Glasgow in 1894, which was not successful owing to its partial solubility in water, and could not be dyed in filament form. This was followed by Bichromate silk by Fuchs and Bernstein, in which the glue or gelatin is insolubilized by potassium or sodium bichromate. Gerard, Mendel, and Ohl worked on producing a gelatin filament, but so far no satisfactory and economical textile filament has been produced as far as can be learned.

OSSEIN FILAMENTS

Ossein is closely related to gelatin and is obtained from bones by dissolving out the mineral part with phosphoric acid and recovering the ossein by evaporating the mother liquor. There are several methods of obtaining the ossein. Helbronner and Valee have prepared such filaments. Early difficulties were brittleness. Carbofil is a German protein fiber obtained by mechanical treatment of horse or ox muscle, previously treated chemically to remove the major portion of soluble proteins. The fibers are 3–8 centimeters long and resemble flax in structure. They are resistant to boiling water and have been used in surgery.

The Swiss have made a protein fiber known as Marena fiber from hides and leather wastes, which may be mixed with wool in textiles.

FILAMENTS FROM LICHENIN, PECTIN, ICELAND MOSS, AND AGAR-AGAR

Vegetable mucilages such as lichenin, pectin, Iceland moss, and agar-agar have been experimented with in England, for use in gauzelike fabrics. By incorporating into the viscous mass before extrusion glycerol, borax, or gluten the fibers become rather flexible. Such fibers are said to be sufficiently resistant to atmospheric moisture and to be nonhygroscopic. Colored fabrics are made by incorporation of ground colored pigments or by spraying on dyes.

ALGINIC ACID FILAMENTS

A synthetic textile fiber has been produced in Germany by Goda from a jellylike substance containing algin (alginic acid) prepared from seaweed by dissolving it in ammoniacal copper solution containing alkali metal hydroxide, and spinning it into a bath containing a salt prepared from furfural and caustic soda, an aliphatic acid, alcohol and formaldehyde. The filaments are afterward treated with solution containing a sulfate and sulfite. Sarason, of Great Britain, also has a method of preparing such filaments; also the Japanese have a method for forming filaments. Nothing is known of their success or their commercial introduction. It is merely cited here to show the possibilities for future synthetic textile filaments and fibers.

PLASTICS [1]

By GORDON M. KLINE

Chief, Organic Plastics Section, National Bureau of Standards

[With 5 plates]

The parade of new applications in plastics went on in 1940 as the industry continued its phenomenal growth, as evidenced by the increased volume of production and greater annual dollar value of the finished products. This progress can be aptly surveyed by a glance at the winners of the 1940 Annual Modern Plastics Competition which drew approximately 1,000 entries, representing the combined contributions of chemists, engineers, designers, molders, and fabricators in extending the frontiers of the plastics industry.

In the architectural classification awards were given for decorative and functional uses of plastics in the beauty salon and theater and for a crystal-clear doorknob resembling the expensive glass knobs formerly imported from Czechoslovakia and Belgium. In business and office equipment, new achievements in telephone equipment, housings for portable sales registers, and drafting devices were recognized. Midget and portable radios in the communications group and ingenious seasonal displays in decorators' accessories were outstanding. The judges selected the woven plastic porch and terrace furniture, transparent acrylic resin tables, and colorful "period" pieces veneered with cast phenolic sheets for top awards in furniture applications. Such prosaic but essential items as bathroom scales, brooms, and shower heads revealed further extension of plastics into the household domain. Plastic diffuse reflectors for fluorescent lamps won most of the honors in the lighting group. Electrical and refrigerator equipment, soldering paddles, and nylon-bristle brushes for industrial purposes represented advances of plastics in machinery and appliances, and transparent oil containers, electric razor housings, and greeting cards were selected from a host of novelty and miscellaneous items. Laboratory dialyzers, portable motion-picture projectors, and arch supports won recognition in the

[1] Reprinted by permission from The Progress of Science, a Review of 1940. Published by the Grolier Society

scientific group, and transparent plastic belts and suspenders, shoes, raincoats, and smocks topped the style and fashion group. In the sporting goods, games, and toys classification, model boats, chessmen, and harmonicas of exceptional interest were made of plastics. The shipping, airplane, and automotive industries were all represented in the awards made in the transport group. Special listing was given to the development of resin-bonded plywood, which has expanded the market for this material to cover many outdoor applications, such as home construction, boats, concrete forms, outdoor signs, airplanes, truck and bus bodies, farm silos, and refrigerator cars.

A consideration of the classification of plastics and of some details of each type will promote a better understanding of what plastics are and why they can take on many important tasks.

SCOPE OF THE PLASTICS INDUSTRY

The dictionary definition of plastics as materials which are "readily responsive to shaping influences" does not place a convenient limitation upon this field. It implies, but does not state, that the material should maintain its new form when the shaping influences are removed. Even this more limited definition of a plastic would include a great variety of materials—from the metals which are readily shaped when heated to the solid rocks of the earth which exhibit zones of flow at great depths because of the pressure of the overlying mass.

The modern plastics industry deals chiefly with moldable materials manufactured from organic compounds, that is, combinations of carbon with hydrogen, oxygen, nitrogen, and other elements. The inorganic molding materials, such as concretes, cements, and ceramics, and also rubber, an organic substance, are not generally included within the scope of the plastics trade as it is known today, inasmuch as the industries utilizing these materials are considerably older and were already individually organized and developed prior to the advent of the newer plastics.

Classification on basis of chemical source.—The four principal types of organic plastics are (1) synthetic resins, (2) natural resins, (3) cellulose derivatives, and (4) protein substances. A brief description of each of these groups will serve to indicate to the reader who is unacquainted with this field the essential characteristics of each type and the distribution of the various commercial plastics according to this classification.

Synthetic resin plastics.—Public interest has probably centered largely upon the synthetic resin plastics because of their multiplicity and versatility. The chemist has been able to produce at will resin-

ous materials having the hardness of stone, the transparency of glass, the elasticity of rubber, or the insulating ability of mica. These synthetic resins, in combination with suitable fillers, are readily molded into products characterized by excellent strength, light weight, dimensional stability, and resistance to moisture, moderate heat, sunlight, and other deteriorating factors. They lend themselves especially to the rapid manufacture of large quantities of accurately sized parts by the application of heat and pressure to the material placed in suitable molds and to the use of original or imitative effects in a variety of colors. Some of the cheap raw materials used in their production include phenol, urea, formaldehyde, glycerol, phthalic anhydride, acetylene, and petroleum. Synthetic resin plastics are known commercially under such trade names as Bakelite, Catalin, Beetle, Glyptal, and Vinylite. They are used in an ever-growing variety of applications, such as electrical parts, automotive parts, closures, containers; costume accessories including buttons, buckles, and jewelry; hardware, tableware, and kitchenware, and miscellaneous novelties.

The powdered molding compositions are generally sold to custom molders who produce the finished parts. Casting resins and laminated resinous products, described in more detail later, are, however, usually made into sheets, rods, or tubes by the manufacturer of the resin. Blanks are cut from these for the preparation of the finished product by machining operations.

Natural resins.—These are more familiarly known to the public by their common names, such as shellac, rosin, asphalt, and pitch, than by the proprietary names attached by manufacturers to molding compositions prepared from them. They are used in industry for the production of the fusible type of molded product as distinguished from the infusible articles formed by some of the synthetic resins. Hot-molding compositions are prepared by mixing shellac, rosin, and asphalts with suitable fillers. Compositions containing chiefly shellac as the binder are used in electrical insulators for high-voltage equipment, in telephone parts, and in phonograph records. The terms rosin and resin are often confused. Rosin is a natural resin recovered as a solid residue after distillation of turpentine from pine tree extracts.

Cellulose derivatives.—The third type of organic plastics, the cellulose derivatives, is probably the most widely used and best known of any of these materials. To this group belong celluloid plastics used for making toys, toiletware, pen and pencil barrels, and the like; cellulose acetate commonly used in the Celanese type of rayon, safety film, and in place of the slightly less expensive nitrated cellulose when noninflammability is desired; and regenerated cellulose,

familiar to all as the wrapping material Cellophane and the common or viscose type of rayon.

The basic raw material, cellulose, is obtainable in fairly pure, fibrous condition as either ordinary cotton or pulped wood. Treatment with chemicals converts cellulose into compounds which are characterized by the ease with which they can be formed into desirable shapes. Cellulose plastics excel in toughness and are especially useful in thin sheets which have remarkable flexibility. These plastics conduct heat slowly and can be made substantially tasteless, odorless, and transparent. Their principal applications, in addition to those mentioned above, include photographic film, safety glass, flexible window material, artificial leather, airplane dopes, and lacquers.

Protein plastics.—These are perhaps best known according to the source of the raw material—for example, casein from skimmed milk and soybean meal from soybeans. These protein substances are thoroughly kneaded into a colloidal mass, which is then formed into sheets, rods, or tubes by suitable presses or extrusion devices. The formed pieces are hardened by treatment with formaldehyde. The finished products, such as buttons, buckles, beads, and game counters, may be machined from blanks cut from the hardened material or may be shaped from the colloidal casein mass and then hardened. This latter process is now common practice because of the shorter curing time required for the thin pieces.

Classification on basis of heat effect.—The plastics used in the molding industry may be divided into two groups, based on their behavior toward heat, as (1) thermoplastic and (2) thermosetting. The thermoplastic materials are permanently fusible, that is to say, they alternately melt or soften when heated and harden when cooled. If they are subjected to very high temperatures, vaporization or decomposition takes place. The cellulose derivatives, some synthetic resins, and most of the natural resins are examples of this type. The thermosetting plastics, on the other hand, may be made permanently infusible. This group is usually further subdivided into three stages on the basis of changes in physical and chemical properties. The product of stage (A) is called the initial condensation product and may be liquid or solid; it is both fusible and soluble. The intermediate or stage (B) product is insoluble and difficultly fusible, but it can be molded by the proper application of heat and pressure. This is the usual condition of the resin in the molding composition when it is received from the manufacturer. Further heating of this material, as in the process of molding, converts it to the final or stage (C) product, which has a permanent set and maximum

hardness, strength, resistivity, and insolubility. Most of the molded products of synthetic resin composition which are on the market belong to the thermosetting type.

HISTORY OF THE DEVELOPMENT OF PLASTICS IN AMERICA

A chronological survey of the development of plastics in America is presented in the following paragraphs. By discussing them in the order of their appearance on the market a better idea of the underlying needs which led to their production and their relative importance in the plastics industry today will be obtained. The special properties which characterized each new material and which in many instances were there by design and not by mere chance alone will be described. The important uses which have been made of these various plastics will be recounted.

Cellulose nitrate plastic.—The oldest of the synthetic plastics is the cellulose nitrate or pyroxylin type. It is amazing that a material so hazardous to handle and so readily decomposed by heat has held an important share of the plastics business for so many years. However, it has many unique properties which until recently have made it the best available thermoplastic material for many purposes. Alexander Parkes, an Englishman, prepared various articles from a solution of cellulose nitrate and camphor during the period 1855 to 1865, but John Wesley Hyatt, an American, is generally credited with being the first to attempt to work with cellulose nitrate as a plastic mass rather than in solution. He is said to have been motivated by a desire to find a substitute for ivory in the manufacture of billiard balls, in order to win a prize offered for that achievement. Although unsuccessful in obtaining the award, Hyatt with his brother, Isaiah S. Hyatt, took out a patent in 1869 for making solid collodion with very small quantities of solvent, dissolving the pyroxylin under pressure, thus securing great economy of solvents and a saving of time. The Albany Dental Plate Company was organized in 1870 to handle the first application of the cellulose-nitrate-camphor plastic. By January 28, 1871, the demand for the material for miscellaneous uses had become sufficiently great to bring about the formation of the Celluloid Manufacturing Co., which moved in 1872 from Albany to Newark, its present location. Today Celluloid is only one of a number of trade names, such as Nixonoid and Pyralin, that are used to designate cellulose nitrate plastics produced by various firms in America.

Cellulose nitrate plastic was one of the first to be used in the automobile, being employed in sheet form as windows in the side curtains of early models. Its flexibility and nonfragility were impor-

tant factors in this application, but its susceptibility in the transparent form to ultraviolet light resulted in rapid deterioration of these sheets. Typical applications of this plastic include bag frames, brushes, buckles, clock dials and crystals, drafting instruments, fountain pens, piano keys, shoe eyelets and lace tips, spectacle frames, toilet seats, tool handles, toothbrush handles, toys, and covers for wooden heels. The contributions of this first synthetic plastic to the plastics industry have been extensive and lasting. It not only paved the way for the advances which have been made in formulation and pigmentation of all thermoplastics, but it also supplied much of the mechanical and operative means of manufacture and fabrication. It was the real pioneer in the development of the market for plastics and in many of their uses.

Shellac plastic.—The next plastic to become of importance in this country was shellac molding composition. Shellac is of natural origin, being produced by an insect which lives upon certain trees in India and southern Asia, and has been known and utilized for many centuries for various purposes, such as a component of sealing waxes, polishes, and varnishes. In 1888, Emile Berliner had worked out the details of the method that made it possible to engrave a sound groove on a flat disk, but means of duplicating these recordings in large numbers remained to be perfected. He tried both cellulose nitrate and hard rubber, but neither of these materials was satisfactory for his purpose. In 1895 he turned to a plastic composition containing shellac as a binder, and soon the technique of molding shellac-base phonograph records was under full development. It remains today the largest single outlet for shellac in the plastic molding field. The properties which make it especially suitable for the manufacture of records are ease of molding, toughness, hardness, fidelity of reproduction, low cost, and the possibility of reusing the scrap material. Developments in the past 20 years have been primarily in its application as a resinous binder for cloth, paper, silk, mica, and other electrical insulating components.

Bitumen plastic.—The third plastic to become industrially important in America was the bituminous type, more commonly known as cold-molded. Emile Hemming was the pioneer in its development in the United States and introduced it on the market in 1909. The raw materials used in the preparation of cold-molded plastics are asbestos, asphalts, coal tar, stearin pitches, natural and synthetic resin, and oils. The asbestos in the proportion of 70 to 80 percent contributes the body of the material and the bituminous or resinous ingredients in the proportion of 20 to 30 percent function as the binder. The molding is done at or near room temperature, hence the name cold-molded. The pieces are removed immediately from the

mold and cured in electrically heated ovens to drive off the volatile constituents, oxidize or polymerize the oils or resins, and so transform the plastic into a hard, infusible state. The cold-molding operation is faster than hot-compression molding since the curing is not done in the mold, but the higher pressures required for cold molding and greater abrasive action of the mineral filler make mold maintenance much more of a problem than it is in hot molding. Typical applications of cold-molded plastics include connector plugs on household electrical equipment, heat-resistant handles and knobs for cooking utensils, and battery boxes.

Phenol-formaldehyde resin.—The first and still the most versatile of the commercial synthetic resins, the phenol-formaldehyde condensation product, was described and patented in 1909 by Leo Hendrik Baekeland. Thus, both the original thermoplastic material, cellulose nitrate plastic, and the original thermosetting material, phenol-formaldehyde resin, were first developed commercially in America. Johann Friedrich Baeyer had reported in 1872 that the reaction between phenols and aldehydes leads to the formation of resins, but no products of industrial interest were obtained for the next 35 years because of the inability of investigators to control the reaction. Baekeland's fifth-mol patent provided this essential feature, and his heat and pressure patent described the technique for converting this resin in a relatively short time into a molded article of excellent mechanical and electrical properties. The basic patents covering the preparation of solutions of this resin and their use in impregnating fibrous sheets to make laminated products were issued to Baekeland in 1910 and 1912, respectively.

The manufacture of Bakelite phenolic plastics was begun in Baekeland's Yonkers, N. Y., laboratory in 1907. The General Bakelite Co. was organized in 1910 and was merged in 1922 with the Condensite Co. and the Redmanol Chemical Products Co. into the Bakelite Corporation. Since the expiration of the basic patent in 1926, many other firms have marketed phenolic resins under other trade names, for example, Durez and Resinox.

An important modification of this general type of resin is the use of furfural, produced from waste oat hulls, in place of formaldehyde for the condensation reaction with phenol.

Typical applications of phenolic plastics include distributor heads, coil parts, switches, and related elements in automobiles and airplanes, camera cases and other housings, corrosion-resistant apparatus, and telephone and radio equipment. In combination with paper and fabrics, phenolic resin produces laminated products which are used for gears, bearings, trays, table tops, refrigerator doors, wall coverings, doors, and counter and cabinet paneling.

Casein plastic.—The discovery of the tough, insoluble, hornlike mass produced by the action of formaldehyde on milk casein is said to have been made by two men who were looking for a composition material to replace slate for blackboards. These two men, Wilhelm Krische and Adolph Spitteler, began production of casein plastic about 1900 in Germany and France, respectively, using the trade name Galalith, meaning milk stone. It was 1919 before successful production in America was realized, and its use has been limited because of the marked variations in climate throughout the year, which lead to warping and cracking of this plastic. Its use is confined to small articles like beads, buckles, buttons, game counters, novelties, and trimming accessories.

Cellulose acetate plastic.—A period of very active development of new plastic materials in America started with the appearance of cellulose acetate in the form of sheets, rods, and tubes in 1927. The firm which pioneered in the development of pyroxylin plastic also introduced cellulose acetate plastics to the American market. This was accomplished by a combination in 1927 of the Celluloid Co. with the Celanese Corporation, already a large producer and consumer of cellulose acetate for rayon manufacture. In 1929 the first cellulose acetate molding powder was marketed for use in compression molding. The appearance of the injection molding press in the early thirties greatly increased the speed with which molded articles could be produced with this thermoplastic material. Cellulose acetate plastics and molding powders are now available from several commercial sources and have outstripped the cellulose nitrate type in the quantity and dollar value of annual production.

Cellulose acetate very early found use as a safety photographic film to replace the hazardous cellulose nitrate product. Many of the applications of this plastic—for example, protective goggles, oil gages, screw-driver handles, and flexible window material—have been brought about by the safety factor introduced by its high resistance to impact. It is employed in practically every make of automobile and the total number of acetate parts involved is well over 200, including such items as knobs, handles, switches, escutcheons, steering wheels, instrument panels, horn buttons, and dials. Some of the trade names for cellulose acetate plastics are Lumarith, Plastacele, and Tenite I.

Urea-formaldehyde plastics.—The appearance of the urea-formaldehyde resinous molding compound on the American market in 1929 meant the extension of unlimited color possibilities into the field of thermosetting molding. Two such urea molding powders, Aldur and Beetle, became available that year, while another, Plaskon, was marketed in 1931. Extensive use of urea plastics in the illuminating in-

dustry has resulted from their efficiency in providing a diffused light, plus their lightness in weight and shock resistance. The fact that they are insoluble, infusible, tasteless, and generally chemically inert has made possible their successful use for bottle closures and lightweight tableware. The urea-formaldehyde resins have also been introduced into the field of laminated plastics as paneling and trim for bathrooms, libraries, and hotel and theater lobbies, in order to take advantage of the many stable colors in which they are produced.

Cast phenolic plastics.—Phenolic resin for casting is prepared in the form of a viscous syrup which is poured into lead or rubber molds and hardened by heating. Products were made as early as 1910 from cast Bakelite resinoids, but in their modern form cast phenolics were first introduced in America in 1928. Cast phenolics are known by such trade names as Catalin, Gemstone, and Marblette. They owe their popularity quite largely to their beauty and decorative value, and this type of plastic is often referred to as the "gem of modern industry." Typical application include advertising igns and display, clock cases, game counters and pieces, radio housings, and lighting fixtures. More recently their ue in indutrial adhesives and laminating varnishes has been promoted.

Vinyl resin plastics.—Resins formed by copolymerization of vinyl chloride and vinyl acetate were first made in the United States by the Carbide and Carbon Chemicals Corporation under the trade name Vinylite in 1928. This type of resin has found its most important uses in phonograph records, coatings for concrete and metals, can linings, adhesives, and electrical insulation. In a highly plasticized form, it is now employed for making transparent belts, suspenders, and shoe uppers. The resins formed from the individual esters—vinyl chloride and vinyl acetate—are also important commercially for the manufacture of wire and cable coverings, coated fabrics, adhesives, and plastic wood-filled compositions. Polyvinyl butyral plastic has been found to be outstandingly superior for use as the binder in laminated glass for the automotive and aircraft industries. Three plants were built for its manufacture during 1937 and 1938, and it has now largely supplanted cellulose acetate in this particular application. Production of vinylidene chloride resin was initiated by the Dow Chemical Co. in 1939, and 1940 saw its successful use in fishing lines and seat coverings.

Styrene resin.—In 1937 the Dow Chemical Company made available a synthetic monomeric styrene of high purity and a corresponding polymeric product, Styron, in clear, transparent form. The Bakelite Corporation also started to manufacture Bakelite polystyrene this same year. The most significant properties of polystyrene are its low power factor and practically zero water absorption.

These remarkable properties make styrene resin exceptionally well suited for radio-frequency insulation. Its transparency and chemical resistance are responsible for most of its other uses, such as bottle closures, refrigerator trim, automotive accessories, and indirect lighting of mileage and other indicators.

Acrylic resins.—The acrylic resins were first prepared industrially in America in 1931 for use in coatings and as a binder for laminated glass. The better-known and very interesting methyl methacrylate resin is a product of more recent origin. The cast resin, called Plexiglas and Lucite, respectively, by its two manufacturers, reached the production stage during 1937–38. The airplane industry has found these cast sheets particularly well adapted to their requirements for gun turret and cockpit enclosures because of their lightness, weathering resistance, nonfragility, and clarity. The resin's high internal reflection makes possible spectacular and useful lighting effects in edge-lighted signs and dental and surgical instruments. This type of resin has been found to be preeminently suited for dentures. Its optical qualities make it suitable for spectacle and camera lenses and for reflectors for indirect highway lighting.

Cellulose acetate butyrate.—The Hercules Powder Co. introduced this material in 1932 as a protective coating base. The Tennessee Eastman Corporation started manufacture of a cellulose acetate butyrate molding composition in 1938 and designated it as Tenite II, the original Tenite being their cellulose acetate molding compound.

Cellulose acetate butyrate compositions are superior to cellulose acetate plastics in weathering resistance and in freedom from warping. The requisite plasticity can be produced with a relatively low percentage of plasticizer and with comparatively nonvolatile and water-insoluble plasticizers. The applications of cellulose acetate butyrate plastic are primarily such as result from its combination of toughness and resistance to weathering, for example, woven furniture for exterior use, automobile accessories, and fishermen's equipment. Its record of achieving new applications during 1940 was outstanding among the plastics.

Ethylcellulose.—The first cellulose ether to be made commercially in America was ethylcellulose. The Hercules Powder Co. began making it in 1935 and the Dow Chemical Co. undertook its manufacture in 1937, marketing their product under the trade name Ethocel. Ethylcellulose plastic has not as yet come into general use for molded parts. Its chief applications to date have been in protective coatings, adhesives, paper and fabric coatings, wire insulation, and extruded strip. Another cellulose ether, methylcellulose, was announced by the Dow Chemical Co. late in 1939. Methocel, as it is called, is water soluble, odorless, tasteless, and nontoxic. It yields films which are greaseproof and highly flexible.

Lignin plastics.—The utilization of waste wood and sawdust for the production of molding compositions has been the objective of a considerable number of investigators for the past 10 years. Wood contains approximately 25 percent of lignin, a complex and highly reactive organic compound. In 1937 a lignin plastic first became available under the trade name Benaloid, manufactured by the Masonite Corporation. The development of lignin molding compositions of both the thermoplastic and thermosetting types was announced in 1939 by the Marathon Chemical Co. The possible commercial applications of this type of plastic have just begun to be explored. The low cost of the necessary ingredients makes this plastic of interest for industrial applications which require large quantities of material, such as certain automotive parts, building units, furniture, and wall paneling.

Alkyd resins.—A survey of plastics would not be complete without mention of the alkyd resins. They are used primarily as coating materials which, incidentally, are the largest single outlet for synthetic resins. Over 75,000,000 pounds of these resins were produced in 1939, out of a total resin production of about 215,000,000 pounds for that year. They are made by the reaction of phthalic anhydride or maleic anhydride with glycerol or other polyhydric alcohols.

Finishes based on these resins, Glyptal, Dulux, and Rezyl, are characterized by rapidity of drying, good durability outdoors, excellent flexibility, tenacious adhesion, and electrical insulating qualities. These resins during the thirties replaced the pyroxylin lacquers to a large extent for finishing the bodies and fenders of motor cars.

Nylon resins.—These polyamide resins are made from polyamines and polybasic acids. They could be called amkyd resins, following the terminology used in the name "alkyd" for resins made from polyhydric alcohols and polybasic acids. The basic raw materials for nylon resins are castor oil from which sebacic acid (a 10-carbon dibasic acid) is obtained, and phenol which by hydrogenation and oxidation yields adipic acid (a 6-carbon dibasic acid). Hexamethylene diamine made from adipic acid, and decamethylene diamine made from sebacic acid are typical diamines used in synthesizing these resins. Nylon resin was made available on a large scale by E. I. du Pont de Nemours and Company, Inc., during 1940. It has already proved its suitability to manufacturer and consumer alike for hosiery and has been accepted as a superior bristle material for tooth brushes, hair brushes, and brushes for miscellaneous industrial purposes.

Coumarone-indene resins.—The manufacture of this type of resin from certain coal-tar distillates was begun in 1919 by the Barrett Co. using the trade name Cumar. In 1929 the Neville Co. marketed such resins as Nevindene. The low softening points and brittleness of these resins have restricted their use to serving as plasticizing

agents and tackifiers with various organic binding materials in rubber compounding, floor-tile compositions, and other industrial applications. Annual production in 1935 was 8,000,000 pounds and the output is said to have increased appreciably in recent years.

Molding technique.—The discovery of the fundamental principle involved in the operation of the hydraulic press is generally conceded to have been made by Blaise Pascal in 1653. The adaptation of this principle to a practical machine is credited to Joseph Bramah in 1795. Little industrial use was made of it until after the discovery of the vulcanization of rubber by Charles Goodyear in 1839. A simple hydraulic rod-type press, between the platens of which a 2-piece mold was inserted, was developed for handling the manufacture of rubber products and was subseqently employed for molding the thermoplastics.

The advent of the phenolic thermosetting resin in 1909 provided the stimulus for introducing features in the compression molding press which would increase the output from a given mold. However, realization of the fully automatic compression molding press has come about only in the last 2 to 3 years. These presses perform all the operations of routine molding of thermosetting plastics, consisting of measuring the charge of molding powder, preheating it, loading it into cavities, closing the mold, opening it slightly for breathing, that is, expulsion of gases, closing it again for a predetermined curing period, opening the mold, ejecting the finished pieces, blowing flash from the cavities and plungers, and then repeating this cycle hundreds and thousands of times with the only manual labor required being to keep the hopper supplied with the molding powder.

The original conception of the injection molding principle is commonly attributed to Edmond Pelouze, who in 1856 developed a die-casting machine for forcing molten metal into a die by mechanical or hydraulic means. The industrial history of the injection molding machine for plastics in the United States is only about 5 years old, a fact which seems almost incredible when one looks at the huge 1940 model capable of taking a mold 3 by 4 feet in cross section and turning out four 36-ounce moldings every minute.

The need for the injection molding machine came with the commercial development in 1929 of the heat-stable thermoplastic molding material, cellulose acetate, which required an uneconomical chilling period when molded by conventional compression methods. The cellulose acetate plastic, however, unlike the older cellulose nitrate type, could be kept hot for a relatively long period in a heating chamber and injected hot into a cold mold, wherein it cooled in a few seconds to a temperature at which it would maintain its shape and hence could be ejected from the mold.

At the close of 1935 there were approximately 75 injection molding machines in use in America, mostly of ½ to 1½ ounces per cycle capacity and suitable only for the molding of small articles, such as buttons, pocket combs, and costume jewelry. The demands of molders for machines of increased capacity and sturdier construction to be used for turning out parts for industrial applications led domestic press manufacturers to construct injection molding machines with radical changes in the design of the heating cylinders, spreading devices, injection plungers, and clamping devices. By combining several cylinders, each feeding into a different inlet in the same mold, parts of considerable size weighing up to 36 ounces can be produced. It is estimated by the Institute of Plastics Research that at the close of 1940 there were in the United States 1,000 injection molding presses, 11,000 compression presses, 550 preform presses, and a rapidly growing number of plastic extruding machines.

SUMMARY OF 1940 ADVANCES

No really new plastics appeared on the market during 1940, but outstanding progress in developing increased volume and new markets can be credited especially to the vinyl ester resins and cellulose acetate butyrate. Vinylidene chloride resin is commanding attention in its applications as high-strength fibers and seat coverings. Nylon resin is entering the industrial field as bristles for brushes used in the textile-printing trade. There was further activity in the manufacture of melamine resins, which, in combination with the chemically similar urea resins, are finding ready acceptance by the automotive industry as a hard, durable, rapid-baking finish for car exteriors.

Improvements in injection and compression molding presses have been concerned primarily with various operating features, particularly heating and automatic controls. The technique of continuously extruding thermoplastic materials also advanced considerably during 1940, and extruded plastics are replacing reed and rattan in woven furniture. A process for forming molds by spraying metal against a model has been perfected to the point where production molds have been made and are being tested in service.

The aircraft industry was spotlighted during the past year, and further important strides were made in the use of plastic plywood for molding airplane wings and fuselages. An outstanding development in this field was the laminated plastic tab for insertion in aileron, elevators, and rudders to aid in balancing and controlling the aircraft during flight. The reinforced plastic contributes a saving in weight and greater rigidity in this part. Other military applications of plastics include transparent plastic windshields for airplanes, luminescent resins for various devices, cellulose acetate chutes for

conveying ammunition from boxes to machine guns, plastic face pieces and lenses for gas masks, molded parts for shells, and the use of synthetic fibers in parachutes.

Resin-bonded plywood in 1940 expanded into many industrial fields. Refrigerator cars constructed largely of this material are said to be 6,000 pounds lighter than the previously used type and to provide an economy in fabrication costs because of an 86.5 percent reduction in the number of joints. Simplification of small-boat construction and improved weather-resistant decking and planking for larger craft have also marked the introduction of this material into the shipbuilding industry. The use of laminated plastic for bearings and cams in high-speed industrial machinery was further extended during 1940. Jigs and fixtures made of laminated plastic represent a new development for light milling operations. Laminated sheets, rods, bars, and tubes of various cross sections and lengths are available so that these tools can be produced with very little machining.

Progress in plastics applications during 1940 may be summed up by noting that many branches of industry, such as the automotive, radio, refrigerator, and mechanical handling fields, which had previously made extensive use of plastics, added new molded parts to their products, and that other manufacturers of consumer goods, faced with military priorities for light and heavy metals, turned to the synthetic plastics as readily available and suitable materials for structural parts of many types of equipment.



SUCCESSIVE STEPS IN THE MANUFACTURE OF A PLASTIC

1. At the starting line are these snowy cotton linters. Taken from the cottonseed after the spinnable cotton has been ginned, these short, fuzzy fibers are bleached and scoured to a fluffy mass of pure cellulose. 2. Into this acetylating mixer go the cotton linters, catalysts, and a vinegary solution of acetic anhydride and acetic acid. Powerful machinery stirs the mixture during reaction. 3. Drastic transformation. Acetylator tips up, and out pours an entirely new substance—cellulose acetate. 4. The cellulose acetate is then hydrolyzed (or ripened) in huge storage jars. 5. Cellulose acetate reappears in cakes which may eventually become photographic film, transparent wrapping material, acetate rayon, or other plastics. 6. The plastic, Tenite, shown here is supplied in granular, blank, and sheet forms for molding. It is available in plain and variegated colors, and in all degrees of transparency from crystal clear to opaque.



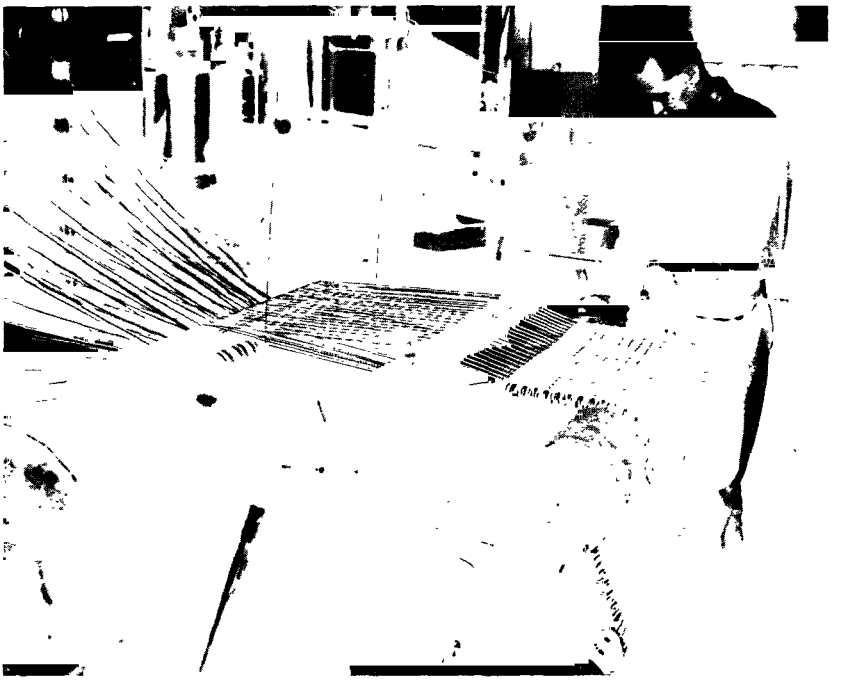
1. PLASTICS FOR OIL CANS.

Clear or tinted transparent plastics make serviceable oilers, unaffected by oils and nonhazardous in the presence of fire. The one shown is of Tenite.



2 PLASTICS FOR SAFETY.

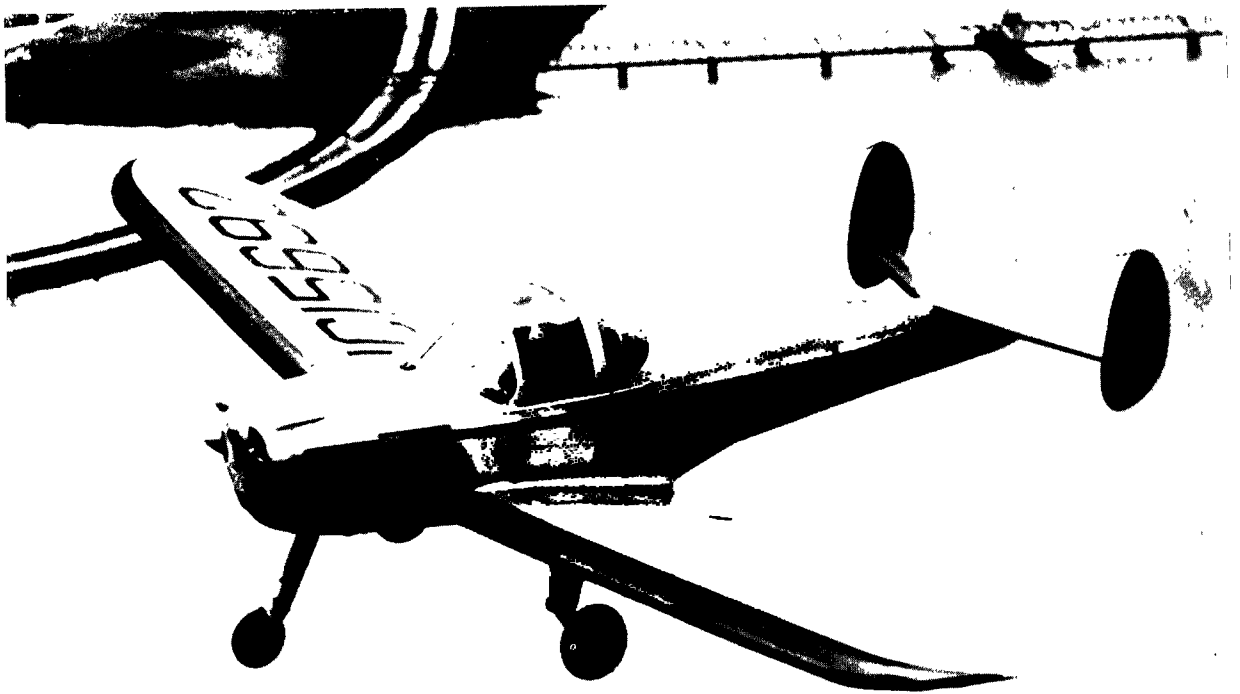
This eyeshield of Plastacele, a cellulose acetate plastic, affords both protection and visibility for many industrial operations.



1. WEAVING A PLASTIC MATERIAL.
Woven Saran makes a rattanlike seat covering

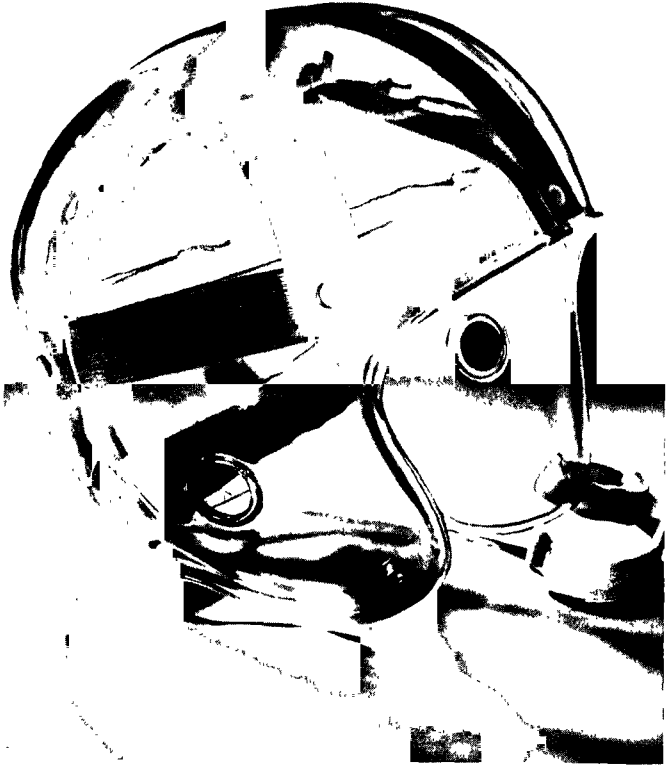


2. NYLON BRUSHES IN INDUSTRY
The operator is inserting new brushes into the machine which is used by a bottling company.



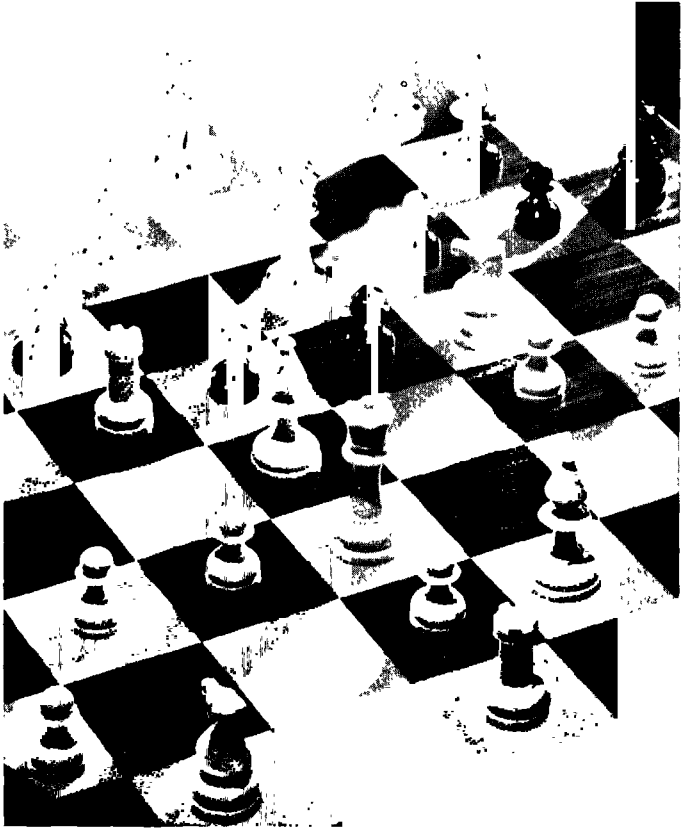
PLASTICS IN AIRPLANE CONSTRUCTION

This new all metal monoplane has a windshield, cockpit enclosure, and rear window all fabricated from clear, polished sheets of Vinylite plastic.



1. PLASTIC HELMET

Plastic football helmets were seen on the gridiron for the first time in the fall of 1940. The one shown is molded of Tenite, a lightweight, tough, resilient plastic.



2. PLASTIC CHESSMEN

These chessmen are injection-molded Tenite.

VITAMINS AND THEIR OCCURRENCE IN FOODS[1]

By HAZEL E. MUNSELL

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INTRODUCTION

The first vitamins were discovered less than 3 decades ago, but since then an almost phenomenal number of substances has been classified in this nutritionally important group. A complete listing at the present time would include as many as 40 or more and there are indications of the existence of still others.

The presence of vitamins in foods was recognized from observations of the almost spectacular effect certain foods have on growth, function, and general well-being of the body. For centuries it had been known that the juice of limes or lemons would prevent or cure scurvy, but there had never been an adequate explanation of this relation. When it was demonstrated that a substance in the outer coating of the whole rice grain would cure or prevent the disease known as beriberi, and that butter and egg yolk contained a substance required for growth and for the prevention of a peculiar type of inflammation of the eye, it became apparent that foods contain certain substances other than protein, carbohydrate, fats, and minerals which are likewise essential for normal nutrition.

The substances in foods credited with these properties were distinguished by descriptive terms as the antiscorbutic, antiberiberi, and antiophthalmic factors, respectively, or on the basis of their solubility, as water-soluble C, water-soluble B, and fat-soluble A. When the name "vitamin," from the term "vitamine" originally used for the antiberiberi substance, was suggested for them as a group they were designated vitamin C, vitamin B, and vitamin A. Since the chemical composition of the vitamins became known, several of them have received names related to their chemical structure. Thus, vitamin C is now known as ascorbic acid, vitamin B_1 as thiamin, vitamin G or B_2 as riboflavin, and vitamin B_6 as pyridoxine.

[1] Reprinted by permission from The Milbank Memorial Fund Quarterly, vol. 18, No. 4, October 1940.

For various reasons a number of the water-soluble vitamins have been grouped together as the vitamin-B complex. Vitamin B_1 and vitamin G were the orginal members of this group which now includes nicotinic acid and vitamin B_6 as well as five or six other factors not mentioned in this discussion.

The number of vitamins actually known to be essential in human nutrition is relatively small. The importance of vitamins A, B_1, and C in the diet is now well known. It is certain that vitamin D is a requirement of children, and while it may be needed by adults as well, perhaps in lesser amounts, this is yet to be demonstrated. Evidence of the significance of riboflavin (vitamin G) in the diet of man has been obtained within the last 2 years, and we now have a clear picture of the external symptoms that follow the use of a diet deficient in this factor. Since the announcement in 1937 of the value of nicotinic acid in the cure of the disease in animals which is comparable to pellagra in man, considerable information has accumulated to establish the value of this substance as a pellagra preventive. There is still some question as to whether nicotinic acid and/or nicotinamide can unreservedly be designated the pellagra-preventing or P–P factor or factors, but there can be no doubt that they are specific in their effect on certain symptoms of pellagra. The substance in foods which is referred to as vitamin K helps promote the clotting of blood, and the supposition now is that it functions in man, as well as in animals, in maintaining a normal level of prothrombin in the blood. An anemia which occurs in chicks given a diet deficient in vitamin K responds to treatment with extracts containing this vitamin.

These are the vitamins definitely known to be required by man. There is also considerable evidence in favor of two others, vitamin E and vitamin B_6. Vitamin E (alpha-tocopherol) has been shown to be important for normal reproduction in several species of animals and it may be required for successful reproduction in the human species as well. Both vitamin E and vitamin B_6 are being actively investigated at the present time.

The importance of the vitamins to normal nutrition is now fully recognized, although there is still a great deal to learn about these substances. In planning foods for the day it is essential to know how to select them for vitamin values as well as for their content of protein, carbohydrate, fat, and minerals. The purpose of this article is to give a brief and not too technical presentation of our knowledge of the properties and food sources of these vitamins. A brief description of the method of quantitative expression used for them and a table of values for vitamin A, vitamin B_1, vitamin C, and riboflavin content of common foods are also included.

PROPERTIES AND FOOD SOURCES

GENERAL CONSIDERATIONS

The most distinctive common characteristic of the vitamins is the fact that they occur in foods in almost infinitesimal quantities and are effective in the body in similarly small amounts. Beyond this they have little in common since they differ markedly both in their physical and chemical properties. Some are soluble in water while others dissolve only in fats and fat-solvents. Some are easily destroyed, especially at high temperatures and when oxygen is present, as when foods are heated in air. Others are fairly resistant to destruction by heat even when heated for several hours at temperatures well above the boiling point of water. In the case of nearly all of them, however, destruction takes place more rapidly in alkaline than in acid solution.

In estimating the vitamin value of foods in the diet it is essential to know and keep in mind the properties of the various vitamins in order to be able to take account of possible losses. Consideration of changes that occur in the vitamin content of foods during processes connected with preservation and preparation, such as storage, freezing, cooking and canning, and drying, is of as much importance as consideration of the vitamin content of the fresh or untreated food. A food which, in its original state, is a perfectly good source of one or more of the vitamins may have its content of one or all of these factors reduced to insignificance as a result of the treatments it undergoes during preparation for consumption. Loss of vitamin value may be brought about not only as a result of inactivation or destruction of the vitamins but also through their mechanical removal by solution, the vitamin passing out of the food material into the surrounding liquid.

While vitamins are found in foods of both plant and animal origin, plants—generally speaking—should be considered the primary sources since animals depend upon plants for their supply of most of the vitamins. This does not mean that the substance responsible for vitamin value in plant tissue is always the same as that having a similar function in animal tissue. Vitamin A, for instance, does not occur in plants, the vitamin-A value of plants being due to certain orange-yellow substances called carotenoids. These are broken down in the liver of the animal so that vitamin A is derived from them, and for this reason the carotenoids are sometimes called the "precursors" of vitamin A.

It is now well known that foods show marked differences both in the kinds and amounts of vitamins they supply. Differences in the vitamin values of different foods do not constitute the only problem

of variation that must be considered, however. There is the equally important matter of variation from sample to sample of a single food item. While it may generally be taken for granted that samples of a given food, selected at different times, will contain the same kind or kinds of vitamins, it does not necessarily follow that they will contain equal quantities of any kind. The idea must not be held with respect to any natural food, that it has a definite and fixed content of any vitamin—unless, perchance, it is zero.

The problem of sample variation in vitamin content of foods is responsible for some of the newer phases of vitamin research, especially in connection with studies related to food production. Some of the factors associated with this variation have been identified but there is still much to be learned. In foods of plant origin, variety in a given kind is very often an important factor in relation to vitamin content. Age and maturity of the product, its size, the amount and kind of fertilizer used in cultivation, the amount of moisture present in the soil, and the degree of exposure to sunlight may also have considerable influence. In foods of animal origin the breed of the animal from which the food comes, as well as its age and physical condition, is sometimes of significance, but the most important factors are the vitamin content of the animal's food and, in the case of vitamin-D value, the length of time the animal was exposed to sunshine. This sums up to the conclusion that values for vitamin content can in no sense be considered exact unless correlated with an adequate knowledge of the conditions that might have had an influence on them.

A point of considerable practical importance in dealing with vitamin values for foods is the fact that relative vitamin potency may easily be discussed by reference to food groups or food types. A diet can be planned on the basis of food groups rather than individual foods, thus lessening the tendency to place undue emphasis on one food that may have been shown to be very rich in a particular vitamin.

VITAMIN A

Properties.—Vitamin A belongs to the group of fat-soluble vitamins and is practically insoluble in water. The pure vitamin, prepared by freezing it out of solution, is a pale yellow, viscous, oily substance. It is not readily broken down by heat but is inactivated by oxidation, especially when heated in a medium where there is free access of oxygen.

As already explained, the vitamin-A value of foods of plant origin is due not to vitamin A, since this substance does not occur in plants, but to the presence of orange-yellow pigments called carotenoids—"precursors" of vitamin A. There are four of these substances:

alpha-, beta-, and gamma-carotene, and cryptoxanthin. Beta-carotene is by far the most important and most widely distributed in natural food products. Cryptoxanthin occurs in only a few foods.

The carotenoids, like vitamin A, are soluble in fats and fat-solvents and are not readily inactivated by heat except as oxygen is present.

Food sources.—The vitamin-A precursors may occur in any part of a plant root, stem, leaf, flower, fruit, and seed. There is considerable variation, however, in the amounts present in foods of plant origin. Many contain them in abundance, and some carry only small amounts or none at all.

An orange-yellow color in foods of plant origin indicates the presence of one or all of the plant carotenoids from which vitamin A may be derived and furnishes a rough index of vitamin-A potency in many vegetables as well as in fruits. Carrots and sweet potatoes are outstanding examples of this relationship. This index holds good where there are yellow and white varieties of a given product. Yellow turnips, yellow peaches, yellow corn, and yellow tomatoes are sources of vitamin A whereas the corresponding white varieties are not. To avoid confusion as to the application of these findings a word of caution seems advisable here. The fact of the presence of vitamin A in yellow varieties of foods is no reason for ignoring the white varieties. They may have values the yellow ones do not have. There is a place in the diet for all types of foods and there is little or no reason for consistently using certain ones and excluding others. Care should be taken to avoid applying factual information on food values in a fanatical way.

A yellow color is not invariably associated with vitamin-A potency, for there are yellow plant-pigments that do not yield vitamin A. A red color has no relation to vitamin-A value and is not indicative of it except that in some foods a red color may mask the orange-yellow of carotene. An example is the red-fleshed tomato containing carotene either in the flesh or the skin.

Experience has led to the recognition that a green color [2] in plants indicates vitamin-A value. Green leaves, and more especially thin green leaves like those of spinach, kale, dandelion, and leaf lettuce, are among the richest sources of vitamin A. Other green foods that are notable in this respect are green string beans and green peppers. The stems of asparagus, celery, and broccoli, and many other plants, may be appraised for vitamin-A value on the basis of greenness. Bleached parts of plants that would normally be green but do not have the green color, either because the chlorophyll never developed

[2] Chlorophyll, the green coloring matter of plants, does not itself form any part of vitamin A, but the high concentration of this vitamin in parts of the plant where chlorophyll functions has led to the suggestion that it may play a role in the formation of the vitamin. Vitamin-A potency in other parts of the plant would in that case be due to substances transported to them for storage.

or because it was destroyed as in the case of winter cabbage, the inner leaves of lettuce, and the bleached stems of asparagus and celery have practically no vitamin-A value.

In general, roots and tubers may be accepted as low in vitamin-A value with the exception of carrots and sweet potatoes, as noted above. Seeds, including nuts, cereal grains, and legumes (peas and beans), are on the whole low in, or totally devoid of, vitamin-A value unless they have some green or yellow color as peas and yellow corn.

Vegetable oils contain little or no vitamin A.

Among the foods of animal origin, eggs and milk are important sources. The hen and the cow do not convert all of the carotene obtained from their feed into vitamin A, and eggs and milk contain both vitamin A and carotene. In both cases the proportion of vitamin A is much higher than that of carotene. The ratio between the quantities of these two substances in milk from different breeds of cows may be significantly different, some breeds, for instance, consistently giving milk which contains a higher proportion of carotene than others. Since vitamin A is soluble in fat and only slightly, if at all, soluble in water, the vitamin-A value of the egg is in the yolk and that of milk is in the cream. Butter is an important source of vitamin A, and other milk products, such as cheese, contain it in proportion to the quantity of milk fat present.

Eggs and milk show wide variations in vitamin-A values. The total quantities of both vitamin A and carotene in eggs and milk are influenced by the quantities present in the feed of the respective animals producing these foods. During the summer months, when green feed is available, milk and eggs may show radically higher values than during other months of the year, although present-day feeding practices, by the use of feeds of high vitamin-A value throughout the year, tend to eliminate seasonal variation.

In contrast to its precursors, the carotenoids, vitamin A has very little color. Inasmuch as milk and eggs contain both carotene and vitamin A, color is of little value in judging their vitamin-A potency. This is especially true of eggs. If the hen derived vitamin-A value from green feed or products rich in carotene, the yolk of the eggs will be deep yellow in color and will have a high vitamin-A value. If the hen did not have access to green feed or other highly colored food, but was given feed containing cod-liver oil, which contains vitamin A but not carotene, then the yolk of the eggs will be very light in color and still will be rich in vitamin A.

Meats vary considerably in their vitamin-A value since much more of this factor is stored by some tissues than by others. Liver, especially, retains large amounts of it when there is an abundance of the vitamin in the diet, which makes it a rich food-source but from the standpoint of cost it can hardly be considered an important one.

Glandular organs, other than liver, contain fairly large amounts of the vitamin but, like liver, they are available in limited quantities. Lean muscle meats contain only small quantities of vitamin A.

Losses of vitamin-A value.—Vitamin A and its precursors are not greatly affected by any of the processes connected with food preservation and preparation unless there is considerable chance for oxidation. Foods that are stored show a loss only after prolonged storage. This is greatest in foods that have been dried preparatory to storing, such as dried grasses and dried fruits. Even though such foods were good sources to begin with, they may lose as much as 50 percent of their vitamin-A value in a few months' time. Boiling and steaming cause practically no diminution in vitamin-A content. Losses have been noted as a result of baking but they are not serious; in roasting, destruction of vitamin A is appreciable.

As would be expected there is little or no loss of vitamin A when foods are canned. During storage the vitamin-A content of canned foods may decrease but this change takes place gradually and usually is not appreciable up to 9 months.

VITAMIN B_1 (THIAMIN)

Properties.—Vitamin B_1 is a white crystalline material that is soluble in water. In plants it seems to exist in relatively simple combination and may be removed fairly easily by extraction with water. In animal tissue it is present in more complex form combined with phosphate.

Vitamin B_1 is described as heat-labile—that is, unstable when heated. Inactivation depends entirely, however, upon conditions under which it is treated. In acid solution it is relatively stable but in neutral or alkaline solution it is readily broken down, the rate of destruction being higher with increase in alkalinity, temperature, and time of heating. The rate of destruction of the vitamin is also higher when it is heated in solution or in mixtures that are moist than when heated in dry mixtures.

Food sources.—Vitamin B_1 occurs in practically all foods derived from plants with the exception of fats and oils, but there are very few concentrated sources. Vitamin-B_1 values of foods seem to be less subject to the influence of conditions of production and are therefore somewhat more constant than other vitamin values.

The relatively low concentration of vitamin B_1 in foods and the lack of sensitivity of the methods for measuring it have not made it possible to determine its distribution in the different parts of plants as closely as in the case of some other vitamins. Seeds, including grains, nuts, and legumes, are known to be among the richest sources. In grains, the vitamin is concentrated in the embryo and outer cover-

ing. In the process of refining, these parts are largely removed, hence the importance in the diet of whole-grain breads and cereals from the standpoint of vitamin B_1.

All fruits and vegetables contain some vitamin B_1. Although none of them is a rich source, they should be considered important sources since they comprise a part of all diets and are usually eaten in relatively large amounts. Potatoes should be considered especially in this respect.

Milk is a good source of vitamin B_1 in that it is generally consumed without having been subjected to treatment other than pasteurization which entails little loss of the vitamin. Eggs are also a good source, the vitamin being in the yolk.

Meats should probably be rated as good sources of vitamin B_1, although there is considerable destruction during cooking. For reasons not yet determined pork has a vitamin-B_1 content two or three times greater than other meats, and the dark meat of chicken may be richer than the light meat. Glandular organs, liver and kidneys for example, are somewhat richer than muscle meats.

Fats and oils do not contain vitamin B_1.

Losses of vitamin B_1.—In considering loss of vitamin B_1 in foods it is essential to keep certain facts clearly in mind: (1) The vitamin is soluble in water; (2) it exists in foods in different combinations which may have a bearing on the ease of removal and also on its destruction; and (3) inactivation of the vitamin depends upon conditions,[3] and the quantity destroyed cannot very well be expressed by a definite percentage but is more a matter of rate of destruction.

When foods are cooked by boiling, the proportion of vitamin B_1 destroyed is relatively small up to cooking periods as long as 1 hour, and generally does not exceed 10 to 15 percent unless the food is distinctly alkaline or has been made so by the addition of soda. The loss by solution, on the other hand, may be considerable, depending, in addition to other factors noted, upon the proportion of water used. Larger amounts of water remove more of the vitamin. The proportion of vitamin B_1 found in water in which food has been cooked has been reported as high as 50 percent of that originally present in the food. If this water is used there will be little loss of the vitamin.

Baking causes only slight, if any, destruction of vitamin B_1 but the higher temperature and longer time required for roasting results in appreciable destruction.

[3] Acid solutions containing vitamin B_1 have been heated as long as 1 hour at 120° C. without appreciable deterioration of the vitamin. In slightly alkaline solutions losses approximated 30 percent during 1 hour of heating at the boiling point of water. Dry mixtures containing vitamin B_1 have been heated at 100° C. for as long as 48 hours and have shown no detectable change in their vitamin-B_1 content.

In canning there is apparently no loss of vitamin B_1 from processing, the greatest loss taking place during blanching or other procedures where there is a chance for solution. There are very few data to support a statement concerning the effect of storage on vitamin B_1 in canned foods. Losses noted were determined after about 6 months' storage and ranged around 40 percent.

Practical information on the inactivation of vitamin B_1 in foods during drying is almost entirely lacking. The vitamin seems to be retained fairly well by foods dried at a temperature of 60° C. but at higher temperatures destruction is probably considerable.

VITAMIN C (ASCORBIC ACID)

Properities.—Vitamin C in its pure form is a white crystalline material with an acid taste and is readily soluble in water. It is inactivated by oxidation and the rate of destruction increases rapidly with increase in temperature. The degree of acidity of the mixture also has a marked influence on the stability of vitamin C. In an acid mixture like tomato juice it is destroyed only slowly, but in less acid solutions the rate of destruction is much more rapid.

Inactivation of vitamin C by oxidation proceeds in two steps. By mild oxidative processes a substance called dehydroascorbic acid is formed. This substance, which functions in the animal body as vitamin C but does not respond to the usual chemical test, may be reduced to ascorbic acid. Under more drastic conditions of oxidation the vitamin is completely inactivated and its activity may not be restored.

Food sources.—Vitamin C may well be called the vitamin of fresh foods. This does not mean fresh from the market, but fresh from the plant or animal that produced the food. One authority has said, "with the exception of ripe seeds, practically all fresh foods of either plant or animal origin contain generous amounts of vitamin C."

Fruits and vegetables are, on the whole, the richest sources of vitamin C. There is a tendency, however, to limit the emphasis to fruits and vegetables that can be eaten raw, and more especially to the citrus fruits and tomatoes. Since these specific products are not only outstandingly rich sources of the vitamin but also retain their potency remarkably well during the various treatments to which they may be subjected, they have come to be considered almost essential in the diet. This tendency should probably not be encouraged to the extent of diverting attention from other fruits and vegetables that are equally important for vitamin C. In some localities and at certain times of the year other fruits and vegetables, if handled so as to conserve their vitamin-C value, might be more economical than citrus fruits or tomatoes.

Other fruits that may be considered important from the standpoint of vitamin-C content are strawberries, blueberries, and cranberries. Among the vegetables, peppers are outstanding in the quantity of vitamin C they contain. Cabbage and other members of the cabbage family, cauliflower and brussels sprouts, and turnips and rutabagas also contain large amounts. Vitamin C occurs in fairly high concentration in all leaves such as spinach, collards, turnip greens, and watercress.

Variation in vitamin content according to variety has been studied more extensively with respect to vitamin C than for any of the other vitamins. Rather wide varietal differences have been shown for apples, tomatoes, oranges, and cabbage. In the case of oranges several other factors are known to influence vitamin-C content, making varietal differences as studied of lesser importance. Fully ripe fruit contains more of the vitamin than partially ripe fruit, and that exposed to sunlight is richer than that from the shaded side of the tree. The vitamin-C content of a given variety of orange decreases progressively as the season advances although this change is less pronounced for some varieties than others. Conditions of cultivation also have an influence, but these are not as well defined as other factors. The extent of differences that exist in the vitamin-C content of oranges may be illustrated by values obtained in the Bureau of Home Economics on a dozen oranges examined individually. These oranges were of uniform size and appearance and were purchased at one time and came from a single bin in a store in Washington, D. C. The vitamin-C content ranged from 24 to 60 milligrams of ascorbic acid per 100 milliliters of juice.

Factors other than variety that may influence vitamin-C content have also been studied with apples and tomatoes. With apples, size is significant. In this fruit the vitamin is concentrated in the skin and in the flesh just under the skin. Since the proportion of skin to flesh is greater in small than in large apples, a small apple contains more vitamin C in proportion to its weight than a large one. In tomatoes there is a gradual increase in vitamin-C content as the fruit matures while during the actual process of ripening there may be a decrease.

Milk and meats should not be considered significant sources of vitamin C. Milk as it comes from the cow contains an appreciable amount, but this is inactivated rapidly as the milk stands. Meats are not important sources because whatever vitamin C they contain is destroyed during cooking. Eggs do not contain vitamin C.

Vitamin C is not present in fats and oils since it is soluble in water and not in fats.

Losses of vitamin C.—Loss of vitamin-C value from foods may occur as a result of inactivation by oxidation or removal of the vitamin by solution.

Consideration of losses from oxidation require mention, at least, of factors pertaining especially to this vitamin. Some fruits and vegetables contain substances called oxidases that accelerate the rate of inactivation of vitamin C by oxidation. These substances in turn are inactivated by heat and are destroyed in a short time when kept at the boiling point of water. Small amounts of copper coming from utensils and containers also catalyze, or hasten the oxidation of vitamin C. Some foods also contain within their tissues an amount of oxygen sufficient to be a factor in the oxidation process.

Deterioration of vitamin C begins in all foods as soon as they are removed from the environment in which they were produced. This is the reason for indicating carefully what is meant by "fresh foods" from the standpoint of vitamin-C content. The rate of inactivation of vitamin C in fruits and vegetables that are allowed to stand seems to depend upon their physical characteristics. Thin leaves like spinach lose vitamin C rapidly and may retain no more than 50 percent after standing 2 or 3 days. Peppers having a smooth compact outer covering, show little loss. In apples the loss is gradual and ripe tomatoes may be stored as long as 10 days without detectable change in vitamin-C content. Rate of inactivation in all such products increases with increase in temperature so that loss is less when they are kept under refrigeration.

In plant products inactivation is more rapid when the plant cells have been opened up so that the vitamin is exposed to oxygen. Decrease in vitamin-C content takes place in vegetables that are prepared for cooking or canning and then allowed to stand. Foods that are chopped or crushed lose vitamin C rapidly and may contain appreciably less of the vitamin after standing only a few hours. The rate of destruction of the vitamin is less, however, at low temperatures in such cases. Expressed juices like orange juice and tomato juice may be stored in covered containers at household refrigerator temperatures for as long as 24 hours with no detectable change in vitamin-C content. Rate of destruction after that time depends upon whether the oxidases have been previously destroyed by heating. Canned tomato juice, after the can is opened, shows little change in vitamin-C content after several days' storage in a refrigerator.

Heat markedly accelerates the rate of destruction of vitamin C and cooked foods are not dependable sources of this vitamin. Tomatoes are a notable exception since they are rich sources to begin with and due to their high acidity they show loss of the vitamin only

after prolonged heating. In foods that contain oxidases destruction of vitamin C during cooking is very rapid at first or until the temperature is reached at which the oxidase is destroyed when it proceeds at a much slower rate. To preserve vitamin-C content during cooking, foods should be cooked quickly. They should also be served immediately since cooked foods lose vitamin C more rapidly when allowed to stand than do raw ones.

When foods are boiled some of the vitamin C they contain may dissolve in the cooking water. This dissolved vitamin may be conserved, obviously, by using the water. The proportion of vitamin C destroyed in foods that are boiled averages 20 to 25 percent while 30 to 40 percent may be present in the cooking water depending upon the amount used.

Foods that must be cooked at temperatures higher than that of boiling water do not retain enough vitamin C to require consideration.

Reduction in vitamin-C content from canning is less than in foods cooked by other methods since air is largely excluded during processing. Decrease in vitamin-C content is greater in foods that are preheated in an open kettle before they are put into the can than in those canned by the cold pack method. Blanching may cause some loss of vitamin C through solution, but this procedure at the same time effects inactivation of any ascorbic acid oxidase present.

Canned foods may be stored several months without showing serious decrease in vitamin-C content, but when deterioration once begins it proceeds rapidly. Inactivation of vitamin C in canned goods is directly and specifically related to the size of the bead space, hence, this should be kept as small as possible. Conditions of storage do not seem to be closely related to rate of loss of vitamin C in canned foods. The question as to whether loss is greater in foods canned in tin or in glass is still in the controversial stage.

In considering canned foods as sources of vitamin C, one important point must be kept in mind. Such foods have been cooked at a fairly high temperature and the cellular structure is largely broken down. If they are allowed to stand after removal from the can or are heated and then allowed to stand they will not have very much vitamin C. Tomatoes are an exception since they retain vitamin C well under most conditions because of their high acidity.

Drying of foods is very destructive of vitamin C. Some dried products—fruits—have been reported as containing small quantities, and sulfured foods are supposed to contain more than others; but the amounts left even in foods that have just been dried are so small that it seems safer on the whole to disregard dried foods as probable sources of this vitamin.

VITAMIN D

Properties.—At least 10 different substances are known to have vitamin-D activity but only two of these are of practical importance. They are vitamin D_2 or activated ergosterol, known also as calciferol, and vitamin D_3 or activated 7-dehydrocholesterol. Ergosterol which is found only in plant tissue, and 7-dehydrocholesterol, which is associated with cholesterol, the sterol in animal fats, are often called provitamins. Under the influence of ultraviolet light (irradiation) they are changed into active forms of vitamin D. The commercial preparation known as Viosterol, is a solution of activated ergosterol in oil.

The relative activity of these two forms of vitamin D is different for different species of animals. A preparation of vitamin D_2 or calciferol, judged by tests with rats to have the same activity as a given preparation of vitamin D_3, will be judged to be considerably less potent when examined by tests with chicks. Thus, while, for a given effect, chicks may require the same amount of vitamin D_3, they will require more vitamin D_2.

Vitamin D (D_2 and D_3) is soluble in fats and is not affected by heat or oxidation.

Food sources.—Vitamin D does not occur to any extent, if at all, in foods of plant origin, but plants do contain the provitamin, ergosterol. Dried plant tissue containing ergosterol acquires properties of vitamin D on exposure to ultraviolet light. Yeast contains large amounts of ergosterol, and irradiated dried yeast is an important source of vitamin D.

The only significant natural sources of vitamin D are among the foods of animal origin. These include milk, eggs, liver, and fish that are rich in oil, like salmon and herring. The value of these foods as sources of vitamin D may well be questioned, however. The quantities of the vitamin that they contain are so small compared to the quantities needed by children for protection against rickets as to be of little practical value in this respect, and if adults require vitamin D it is difficult to believe that the quantity is as small as that ordinarily supplied by the use of these foods. This statement does not apply to fish-liver oil, which is the richest natural source of vitamin D. Since foods of animal origin are the only ones that contain vitamin D naturally, and they contain only vitamin D_3 this form of the vitamin is sometimes referred to as natural vitamin D.

The vitamin-D content of milk and eggs may be increased by feeding the animals producing these foods some rich source of the vitamin. Cows may be given irradiated yeast. "Metabolized" vitamin-D milk is produced in this way. The greater proportion of

the vitamin D in such milk will be vitamin D_2 with the small quantity of natural vitamin D normally present. Eggs of high vitamin-D activity are obtained by including cod-liver oil in the hen's feed so that eggs generally contain only natural vitamin D.

Milk may also be enriched in vitamin D by irradiating the cow, by irradiating the milk, or by adding concentrates of the vitamin directly to the milk. Only the last two methods have been used to any extent commercially.

RIBOFLAVIN (VITAMIN G)

Properties.—Pure riboflavin is a yellow crystalline material readily soluble in water, giving a yellow green-fluorescent solution. Riboflavin is not readily destroyed by heating but is less stable in alkaline than in acid solution.

As it occurs in nature, riboflavin forms part of a protein phosphoric acid complex that must be broken down before the pure vitamin can be obtained.

Food sources.—Food sources of riboflavin are less completely known than are sources of the other vitamins so far discussed. This is due partly to its later discovery but largely to the lack of a satisfactory method of measurement.

Milk, eggs, and lean meats are the richest sources. The yolk and the white of eggs contain it in about the same concentration. As riboflavin occurs associated with protein, it is present in milk in the skimmed milk and not in the butterfat.

In plants, riboflavin seems to be concentrated in the green parts. Thin green leaves are especially rich sources. Green stems are much richer than the flower or the root. Although the vitamin is more concentrated in the green parts, the bleached parts of plants are not devoid of it, as they are of vitamin A. Most root vegetables and tubers contain some riboflavin. In fact, riboflavin is present in practically all vegetables of one sort or another.

Seeds vary considerably in the amounts of riboflavin they contain. Legumes, peas, beans, and especially soybeans are good sources, while nuts and cereal grains are not so rich. The germ portion of the seed usually contains a high concentration of riboflavin, as it does of vitamin B_1.

In general, fruits are low in their content of riboflavin. The majority can be rated only fair and some fruits such as grapes, lemons, oranges, and grapefruit, contain little more than a trace. If there is a basis for classifying fruits as to riboflavin content, it is not apparent in the few data now available.

Fats and oils have already been described as not containing the water-soluble vitamins B_1 and C. They are also about the only foods that do not contain at least traces of riboflavin.

Losses of riboflavin.—There is not a great deal of information available on losses of riboflavin in foods. From the fact that the vitamin is soluble in water it might be anticipated that there would be loss during boiling or any process where food is kept in contact with water for any length of time. It will be remembered, however, that in foods riboflavin is combined with other substances. The difficulty experienced in removing the vitamin from foods by those who have undertaken quantitative estimation by chemical tests indicates that probably no great amount would be removed during boiling, blanching, or soaking.

Riboflavin is described as heat-stable, which again might lead one to think that losses during cooking would be small. Milk whey, having an acidity comparable to that of tomato juice, was found to lose only 10 percent of its riboflavin value when heated at the boiling point of water for 1 hour, and 4 hours of heating was required to reduce the original value by 30 percent. When the mixture was made only slightly alkaline, the rate of destruction reached 30 to 40 percent for 1 hour of heating. This is a clear indication that conditions within the medium influence inactivation of riboflavin as they do inactivation of vitamin B_1. Under similar conditions, in a liquid medium the rate of destruction of riboflavin was found to be slightly less than the rate of destruction of vitamin B_1. This relieves the situation relative to lack of specific information on loss of riboflavin in foods, since any measures designed to reduce losses of vitamin B_1 during boiling apparently would also operate to protect against losses of riboflavin.

In contrast to vitamin B_1, riboflavin is less stable when heated in a dry mixture than in one that is watery or even only moist. This may afford partial explanation of the fact that the most extensive losses noted have been in the baking, roasting, and frying of meats. These ranged from 30 to 60 percent.

There is no indication that storage causes loss of riboflavin irrespective of whether foods are fresh, canned, or dried. Canning per se does not seem to reduce the riboflavin content of foods or at least not significantly. Information on the effect of drying is not available.

NICOTINIC ACID (PELLAGRA-PREVENTING FACTOR)

Properties.—Nicotinic acid is a white crystalline substance soluble in water and fairly resistant to heat. The amide, nicotinamide, is also effective as a pellagra preventive. Like some of the other vitamins discussed, nicotinic acid as present in foods is combined with other substances and is not easily removed until these complex compounds are broken up.

Food sources.—No consistent effort has been made to determine the nicotinic acid content of foods accurately. Most of the studies along this line have been concerned with determination of pellagra-preventing value directly. Some of these studies have been made with dogs as subjects and some with human beings. It is difficult to correlate the two kinds of data. Appraisal of pellagra-preventing value of foods on the basis of content of nicotinic acid depends upon the quantity of this substance required for the cure and prevention of pellagra; and this has not yet been definitely determined, although it can be stated approximately.

Milk, lean meats, eggs, fish, liver, and some vegetables have long been known to be valuable in the cure and prevention of pellagra. Among the vegetables, green leaves are especially effective, and the legumes (peas and beans) and tomatoes have some value.

Losses of nicotinic acid.—The pellagra-preventing value of foods is not reduced easily. Foods have been heated in an autoclave or pressure cooker as long as 6 hours without showing a decrease in effectiveness. Canned foods seem to be equally as good as the corresponding fresh ones.

VITAMIN K (THE ANTIHEMORRHAGIC VITAMIN)

Properties.—Vitamin K is one of the newer vitamins. It is a colorless or slightly yellowish crystalline substance soluble in fats but not in water. It seems to be resistant to heat but is destroyed by alkalies and certain substances that bring about oxidation.

Food sources.—Vitamin K is fairly widely distributed in foods. It occurs abundantly in green leaves, alfalfa having been one of the chief sources from which concentrates have been prepared. Flowers, roots, and stems of plants contain less than leaves. The vitamin is present in soybean oil and some other vegetable oils and in tomatoes. It is not present in fish-liver oils, but decomposed fish meal has been the source of a substance having vitamin K activity, differing slightly from the vitamin K of alfalfa. A number of compounds are known to have properties ascribed to vitamin K but how many of these occur naturally is not known.

VITAMIN E

Properties.—Vitamin-E activity is shown by several substances. The one of most importance from the standpoint of its natural occurrence is alpha-tocopherol. This has been separated from wheat-germ oil and cottonseed oil as a light yellow viscous oil.

Food sources.—Vitamin E occurs in many of the various types of foods considered essential in a well-balanced diet and it is not difficult to obtain an adequate supply. Foods known to contain vita-

min E in abundance are milk, meat, eggs, whole seeds, including both cereal grains and legumes, and lettuce. It is also present in many vegetable oils including, in addition to the two already mentioned, corn oil, rice oil, and Red Palm oil.

Losses of vitamin E.—Vitamin E is soluble in fat and occurs associated with oils. It is stable toward heat but is inactivated when oils containing it become rancid—presumably because of oxidation.

VITAMIN B_6 OR PYRIDOXINE

Properties.—Vitamin B_6 is a white crystalline substance and is soluble in water. It is stable toward heat even in alkaline solution, but is destroyed by long exposure to light.

Food sources.—Vitamin B_6 is found in seeds; in some vegetable fats and oils such as linseed oil, peanut oil, rice oil, soybean oil, cottonseed oil, corn oil, and wheat-germ oil; and in butterfat, beef fat, meats, and fish. Most vegetables and fruits are poor sources.

THINGS TO REMEMBER

The array of information relating to the vitamins is extensive and complex. Unless one is making almost constant use of it, it is next to impossible to keep even the essential details in mind, and very few people wish to be hampered by the need of a pocket handbook in order to remember their vitamins. In the selection and preparation of foods for a diet adequate in vitamin content a few rules or summary statements are usually sufficient. Those given below are suggested as helpful and others may be formulated if need requires.

1. Use a variety of all types of foods giving especial attention to the use of milk, eggs, green leafy vegetables, *fresh* fruits and vegetables, lean meats, and whole-grain cereals and breads.
2. To avoid loss of vitamin value in cooking:

   Cook foods as quickly as possible.

   Use small amounts of water and use any that is left. Special utensils are not necessary for so-called waterless cookery.

   Steaming is an excellent way to cook many vegetables and some other foods.

   Do not peel vegetables or fruits and cut them up and then let them stand before cooking. Cooking them whole and with the outer covering on helps preserve vitamin content.

   Never add soda to vegetables during cooking. It serves no useful purpose and makes for destruction of vitamins. Cook green vegetables in an open kettle and they will stay green.

   Serve foods as soon as possible after they are cooked.

   Do not fry foods if they can be cooked in some other way. Frying and roasting are very destructive of vitamins.
3. Give very careful attention to sources of vitamin B_1 in the diet. It is more difficult to obtain an adequate amount of this vitamin than any of the others. It is probably the one in which American diets are most deficient.

Take special care to conserve the vitamin B_1 in foods during cooking. Many of the foods that contain an abundance of vitamin B_1 are cooked before being eaten, and next to vitamin C, vitamin B_1 is the vitamin most likely to be lost when foods are cooked or canned. The precautions necessary to conserve vitamin B_1 will conserve other vitamins as well.

4. Store foods at low temperatures and in closed containers.

5. Do not chop or crush fresh fruits and vegetables and allow them to stand. They lose vitamin C rapidly.

6. Frozen foods have practically the same vitamin content as fresh ones. Care must be taken to conserve it during preparation for serving. Do not defrost and then allow to stand. If frozen foods are to be cooked put them on to cook while they are still frozen and use all of the liquid.

7. Dried foods are not especially recommended for vitamin value.

8. Canned foods retain vitamin value well, with the possible exception of vitamin C, provided they have not been stored too long. To obtain full value, use the entire contents of the can. Canned foods are cooked foods and should be treated accordingly.

9. In canning foods observe the same precautions for conserving vitamin content as suggested for cooking.

VITAMIN VALUES

As soon as the existence of any one of the vitamins was recognized it became a matter of concern to know not only in what foods it occurred but also in what quantities. The development of methods of measurement was, therefore, of considerable importance. Chemical identification of the vitamins has usually not been made until some time after their discovery and for this reason development of chemical or physical methods of measurement proceeded uncertainly.

Many of the studies on the physiological effects of the vitamins have been made with laboratory animals. It was natural in some of these studies for information to be obtained on the relation between the quantity which an animal ate of a food known to contain a particular vitamin and the response of that animal in terms of growth, or cure or prevention of the disease associated with the vitamin. As these observations were made, consideration was given to the possibility of using a relationship of this kind as the basis of a quantitative method of measurement for the vitamin concerned. Methods of determination in which the reactions of animals are used are called biological methods.

To determine actual vitamin content by a biological method it is necessary to carry out a test in comparison with a substance containing a known amount of the vitamin in question. When the biological methods were first suggested, this condition could not be met because the chemically pure vitamins had not yet been prepared and natural products vary too much to be used as reference materials. As a result of this situation it became the custom to express content with respect to a particular vitamin in terms of the quantity

required to produce a given response in the animal used and under the conditions specified for the test. Such a quantity was known as a "unit." Several of these biological units have been defined and used but the best known are probably the Sherman units for vitamins A, B_1, and C, and vitamin G or B_2 (riboflavin).

As interest in the importance of the vitamins increased, attempts were made to devise more satisfactory methods of evaluating them. A committee appointed by the Health Organization of the League of Nations has established standards of reference called International Standards of Reference for vitamins A, B_1, C, D, and E to be used in determining the content of these vitamins in foods and other materials. A definite quantity of each standard was specified as the International unit in terms of which the content of the respective vitamin was to be expressed.

Definitions of the International Units for Vitamins A, B_1, C, and D

Vitamin A.—The International unit of vitamin A is the vitamin-A activity of 0.6 microgram (0.0006 milligram) of the International Standard beta-carotene. One U. S. P. (United States Pharmacopoeia) unit of vitamin A presumably has the same value as 1 International unit (I. U.) of vitamin A.

Vitamin B_1.—The International unit of vitamin B_1 is the vitamin-B_1 activity of 3.0 micrograms (0.003 milligram) of the International Standard crystalline thiamin chloride (vitamin B_1). One U. S. P. (United States Pharmacopoeia) unit of vitamin B_1 has the same value as 1 International unit (I. U.) of vitamin B_1.

Vitamin C.—The International unit of vitamin C is the vitamin-C activity of 0.05 milligram of the International Standard crystalline ascorbic acid (vitamin C). One U. S. P. (United States Pharmacopoeia) unit of vitamin C has the same value at 1 International unit (I. U.) of vitamin C.

Vitamin D.—The International unit of vitamin D is the vitamin-D activity of 1 milligram of the International Standard solution of irradiated ergosterol in oil. One U. S. P. (United States Pharmacopoeia) unit of vitamin D presumably has the same value as 1 International unit (I. U.) of vitamin D.

Enumeration of vitamin potency in terms of International units is now the accepted mode of expression. As more satisfactory chemical and physical methods of measuring vitamin content are developed, this somewhat cumbersome device will doubtless be abandoned for the more usual procedure of giving composition on the basis of weight of chemical substance. This is already the case with vitamin C where values are given more often in terms of milligrams of ascorbic acid per gram or per 100 grams of material than in terms of International units.

No International Standard for riboflavin has been established. The Sherman or Sherman-Bourquin unit is frequently used for denoting vitamin-G potency, otherwise riboflavin is given directly as milligrams or micrograms of riboflavin.

Values for vitamin-A, vitamin-B_1, and vitamin-C content of foods and other materials determined prior to the adoption of the International Standards of Reference are for the most part expressed in terms of the Sherman units. For some foods the only values available are expressed in these units and for this reason attempts have been made to derive factors showing the relation between the Sherman and the International units. Since there has been some divided opinion as to what these should be, it seems well to reemphasize the fact that a biological unit does not have an exact value. These units are defined in terms of animal behavior which, however well controlled, is certain to vary. This simply means that the ratio between an International unit and the corresponding biological unit varies according to conditions, and a fixed figure cannot be established for it. Values expressed in International units which have been derived from Sherman unit values by use of conversion factors cannot be considered more than rough approximations. International unit values so obtained should be clearly designated if presented with other material. The ratios given below for these two units represent general experience with comparative values.

Suggested Interrelation of Sherman Units for Vitamins A, B, C, and G and the Corresponding International Units

Vitamin A.—Sherman units of vitamin A corresponding to 1 International unit of vitamin A have been found to vary from 0.8 to 2.5. The ratio of 1.5 is suggested as most representative, that is, 1 Sherman unit of vitamin A=0.7 International unit.

Vitamin B_1.—Sherman unit values of vitamin B_1 corresponding to 1 International unit of vitamin B_1 have been found to vary from 0.7 to 4 or 6 Sherman units. The most general relation for the majority of values obtained by the Sherman technique is suggested as 1 Sherman unit equivalent to 1 International unit.

Vitamin C.—One Sherman unit of vitamin C is generally considered equivalent to 10 International units.

Riboflavin.—One Sherman-Bourquin unit of vitamin G is equivalent to 3.0 to 3.5 micrograms of riboflavin.

VALUES FOR THE VITAMIN CONTENT OF FOODS

For some purposes, and especially for dietary calculations, it is desirable to have a set of values showing the quantities of the various vitamins in different foods. In the general discussion of food sources of the vitamins it was made clear that no food has a fixed and invariable content of any vitamin. Values for different samples of any food may vary over wide ranges depending upon the factors that influence the content of the vitamins it contains. The derivation of average values, in the strict sense of this term, is not possible without using an unreasonable amount of descriptive material con-

cerning each individual food item. In lieu of this it might seem advisable to indicate a range in place of a single value. The difficulty in that case is that anyone requiring a single value will use the median of the range which may not be in any sense the best value to use. This reduces the problem to one of arbitrarily selecting what are considered the most representative values.

The values in the table presented here, which is offered as an aid to those who must use single values expressive of vitamin content, were selected on this basis. The selections were made from a summary of all of the data that could be obtained in the literature or elsewhere up to July 1, 1940. Careful consideration was given to the methods of analysis used and the nature of the food material studied. The values given should be taken as applying to foods that are reasonably fresh and of good quality. This is especially important to keep in mind relative to vitamin-C values. "Market fresh" vegetables are often far from "fresh" as far as vitamin-C content is concerned. Adjustments should be made in the vitamin-C values for fruits and vegetables, especially leafy vegetables, when the products to which they are being applied are not strictly fresh.

Some values in the table may differ materially from corresponding ones in other summaries. Too much concern should not be felt over such discrepancies, perhaps, since all values of this kind are, as explained, arbitrarily selected and their approximation to actual fact is problematical in any case. If specific information about a food is available, other values might be selected as more suitable.

TABLE 1.—*Values selected as representative of the vitamin-A, vitamin-B_1, vitamin-C, vitamin-D, and riboflavin content of common foods*

[Unless otherwise stated, the values given are for the edible portion of the fresh food] †

Food material	Vitamin A	Vitamin B_1	Vitamin C	Vitamin D	Riboflavin vitamin G
	Units per 100 grams [1]				
	Int.	*Int.* [2]	*Int.* [3]	*Int.*	*Sherman* [4]
Alfalfa leaf meal, dried	8, 000	------	----------	------	500
Almond	75	75	----------	------	200
Apple	75	15	(30–400) av. 100	------	10
Apricot, fresh	4, 000	10	100	------	17
Apricot, dried	5, 000	30	60	------	35
Artichoke, Globe	200	60	175	------	Fair
Artichoke, Jerusalem	----------	50	115	------	----------
Asparagus, green	700	70	700	------	40
Asparagus, bleached	0–50	50	650	------	Fair
Avocado	100	30	400	------	30
Banana	300	15	200	------	30
Barley	0	120	0	------	3
Beans, snap:					
Green	1, 000	25	300	------	40
Wax	0	25	300	------	40

See footnotes at end of table.

TABLE 1.—*Values selected as representative of the vitamin-A, vitamin-B_1, vitamin-C, vitamin-D, and riboflavin content of common foods*—Continued

Food material	Vitamin A	Vitamin B_1	Vitamin C	Vitamin D	Riboflavin vitamin G
	Units per 100 grams [1]				
	Int.	*Int.* [2]	*Int.* [3]	*Int.*	*Sherman* [4]
Beans, shelled:					
Lima	500	115	600	------	100
Runner	1, 000	100	500	------	----------
Soybean	200	175	800	------	100
Beans, shelled, dried:					
Lima	100	175	0	------	300
Navy	0	170	0	------	----------
Red kidney	----------	150	0	------	----------
Soybean	100	400	----------	------	300
Beef, lean	50	40	0	------	75
Beet	0	15	100	------	10
Beet tops	Excellent	------	1, 000	------	150
Blackberry	150	15	140	------	----------
Black-eyed peas (*see* Cowpeas).					
Blueberry	100	15	----------	------	----------
High bush	----------	------	120	------	----------
Low bush	----------	------	90	------	----------
Brazil nut	10	350	----------	------	----------
Bread:					
White	Trace	20	0	------	0
Whole wheat	Trace	100	0	------	30
Rye	Trace	70	0	------	----------
Broccoli, entire plant	9, 000	37	1, 400	------	75
Flower	5, 000	45	2, 000	------	80
Leaf	16, 000	45	2, 500	------	150
Stem	1, 000	25	----------	------	----------
Brussels sprouts	200	60	1, 500	------	----------
Buckwheat	----------	150	0	------	----------
Butter, average	2, 400	------	0	80	----------
From cows on dry feed	1, 200	------	0	40	----------
From cows on green feed	4, 000	------	0	150	----------
Cabbage, head:					
Young, partly green	100	25	1, 200	------	30
Mature, bleached	0	25	1, 200	------	15
Red	----------	------	1, 200	------	----------
Chinese	2, 000	25	800	------	15
Cantaloupe	300	20	600	------	20
Carrot	2, 100	20	100	------	20
Cauliflower	30	50	1, 500	------	35
Celery stalks:					
Green	1, 000	10	100	------	10
Bleached	10	10	100	------	----------
Chard	9, 000	Fair	750	------	30
Cheese:					
Cheddar	2, 000	15	0	------	250
Cottage	500	------	0	------	Good
Cream	2, 100	------	0	------	60
Cherry	15–550 (av. 200)	15	200	------	----------
Chicken, muscle:					
Dark	----------	50	----------	------	Excellent
Light	----------	30	----------	------	Excellent
Clam	14	7	----------	------	----------
Codfish	5	30	0	------	Good
Cod-liver oil	(*)	0	0	(*)	0
Collards	7, 000	50	800	------	100

See footnotes at end of table.

TABLE 1.—*Values selected as representative of the vitamin-A, vitamin-B_1, vitamin-C, vitamin-D, and riboflavin content of common foods*—Continued

Food material	Vitamin A	Vitamin B_1	Vitamin C	Vitamin D	Riboflavin vitamin G
	Units per 100 grams [1]				
	Int.	*Int.* [2]	*Int.* [3]	*Int.*	*Sherman* [4]
Corn, sweet:					
White	0–50	45	200	------	------
Yellow	500	45	200	------	20
Corn dried:					
White	0	100	0	------	Fair
Yellow	550	100	0	------	Fair
Corn oil, refined	0	0	0	------	0
Cottonseed oil, refined	0	0	0	0	0
Cowpea:					
Fresh	------	------	130	------	------
Dried	50	300	------	------	100
Cranberry	20	------	225	0	0
Cream, 20 percent	600	10	------	Traces	------
Cucumber	20	15	200	------	8
Currant:					
Black	400	10	3, 000	------	------
Red	------	15	900	------	------
Dandelion	12, 000	------	2, 000	------	Good
Dates, cured	150	25	0	------	15
Dock, leaves	14, 000	------	------	------	Good
Egg, whole	1, 000	50	0	------	110
White	0	0	0	------	100
Yolk	2, 800	140	0	------	115
Eggplant	35	15	200	------	10
Endive (escarole)	15, 000	28	400	------	40
French	Good	25	------	------	20
Fig:					
Fresh	50	25	30	------	15
Dried	60	22	0	------	25
Flour:					
White, patent	0	30	0	------	------
Whole wheat	------	160	------	------	Fair
Garden cress	Excellent	30	------	------	------
Gooseberry	------	------	500	------	------
Grape	Trace	15	60	------	8
Grape juice	------	------	30	------	------
Grapefruit	0	23	850	------	Trace
Juice	0	25	900	------	Trace
Canned	0	25	800	------	Trace
Guava	200	14	1, 500	------	3
Haddock	5	5	0	------	Good
Halibut	------	30	------	------	------
Hazelnut	100	220	------	------	------
Heart:					
Beef	Trace	200	------	------	300
Lamb	Trace	200	------	------	------
Pork	------	180	------	------	------
Honey	0	0	0	0	0
Horseradish	------	------	2, 000	------	------
Huckleberry	------	------	800	------	------
Kale	20, 000	50	2, 500	------	200
Kidney, beef or veal	1, 000	60	------	------	700
Lamb	1, 000	75	------	------	------
Pork	------	150	------	------	------
Kohlrabi	------	20	1, 200	------	------
Lamb, muscle, lean	------	80	------	------	70

See footnotes at end of table.

TABLE 1.—*Values selected as representative of the vitamin-A, vitamin-B_1, vitamin-C, vitamin-D, and riboflavin content of common foods*—Continued

Food material	Vitamin A	Vitamin B_1	Vitamin C	Vitamin D	Riboflavin vitamin G
	Units per 100 grams [1]				
	Int.	*Int.* [2]	*Int.* [3]	*Int.*	*Sherman* [4]
Lard	4	0	----------	0	0
Leek	Fair	50	400	------	Fair
Lemon juice	0	10	900	------	Trace
Lentils, dried	Trace	170	0	------	105
Lettuce, green	4, 000	25	250	------	75
Bleached	100	25	250	------	15
Romaine or cos	800	------	----------	------	30
Lime juice	----------	------	750	------	----------
Liver, beef	9, 000	75	Fresh 750	45	600
Calf	7, 000	70	Fresh 650	15	550
Chicken	Excellent	75	Fresh 450	50	Excellent
Lamb	Excellent	75	Fresh 750	20	550
Pig	Excellent	100	Fresh 525	45	600
Mango	1, 500	30	600	------	20
Milk	----------	------	Raw 40	------	----------
Whole fresh, average market.	110	20	Past. 25	2	75
From cows on dry feed	55	20	Raw 30	1	60
From cows on pasture	175	20	Raw 50	3	80
Whole dried:					
Average	875	120	0	16	500
From cows on dry feed	450	------	0	8	----------
From cows on pasture	1, 400	------	0	24	----------
Skim	2	15	0	------	Excellent
Skim, dried	20	120	0	------	600
Molasses	0	0	0	------	----------
Mushrooms	0	30	Trace	------	----------
Mustard greens	Excellent	45	2, 500	------	Excellent
Oats (rolled or oatmeal)	Trace	180	0	0	35
Okra	400	40	400	------	Fair
Olive, canned:					
Green	190	------	0	------	----------
Ripe	125	2	0	0	0
Olive oil, refined	0	------	----------	0	----------
Onion:					
Green	Fair	------	275	------	----------
Mature	0	10	160	------	30
Orange juice	45–350	30	{450–1, 200 av. 900}	------	5
Oyster	140	------	5	------	----------
Papaya	2, 500	25	900	------	60
Parsley	30, 000	------	2, 000	------	----------
Parsnip	Trace	40	450	------	----------
Pea:					
Green, fresh	1, 000	140	500	------	65
Green, dried	1, 200	175	----------	------	100
Peach:					
White	5	10	200	------	----------
Yellow	1, 000	10	200	------	20
Yellow, dried	3, 000	------	0	------	----------
Peanut:					
Jumbo	0	320	----------	------	Good
Roasted	----------	90	----------	------	----------
Spanish	----------	300	----------	------	250
Spanish, roasted	----------	60	----------	------	----------

See footnotes at end of table.

TABLE 1.—*Values selected as representative of the vitamin-A, vitamin-B_1, vitamin-C, vitamin-D, and riboflavin content of common foods*—Continued

Food material	Vitamin A	Vitamin B_1	Vitamin C	Vitamin D	Riboflavin vitamin G
	Units per 100 grams [1]				
	Int.	*Int.* [2]	*Int.* [3]	*Int.*	*Sherman* [4]
Pear	10	15	50	------	20
Pecan	400	350	----------	------	100
Pepper:					
Green	5, 000	10	2, 500	------	40
Red	5, 000	10	3, 000	------	---------
Pineapple	90	25	500	------	12
Juice, fresh	----------	30	600	------	---------
Juice, canned	----------	25	300	------	---------
Plum	----------	35	100	------	15
Pork, muscle, lean	Trace	400	----------	------	75
Potato, average	30	40	250	------	15
New	----------	------	350	------	---------
Stored, old	----------	------	100	------	---------
Prune:					
Fresh	1, 500	20	----------	------	---------
Dried	2, 500	50	50	------	Good
Pumpkin	2, 500	15	60	------	15
Quince	----------	------	250	------	---------
Radish	Trace	20	400	------	10
Raisin	50	30	0	------	---------
Raspberry	----------	10	600	------	---------
Rhubarb	Trace	------	400	------	---------
Rice:					
Brown	Trace	75	0	------	50
Polished	0	10	0	------	Trace
Roe	2, 000	30	100	------	Fair
Rutabaga:					
White	0	15	400	------	---------
Yellow	25	15	400	------	---------
Rye	0	140	0	------	Fair
Salmon, canned:					
Chum	30	------	----------	225	---------
Chinook	750	------	----------	275	---------
Pink	100	------	----------	625	---------
Red	325	Trace	0	800	75
Sardine	----------	10	----------	Good	Good
Soybean (*see under* Bean).					
Spinach	25, 000	40	1, 500	------	125
Squash:					
Summer	1, 000	15	----------	------	15
Winter	4, 000	15	100	------	25
Strawberry	Trace	Trace	1, 000	------	Trace
Sweet potato	3, 500	30	400	------	30
Tangerine	----------	30	700	------	10
Tomato, mature:					
Green	700	23	260–600 av. 450	------	15
Ripe	1, 000	25	260–600 av. 450	------	20
Juice, fresh	1, 000	25	av. 450	------	---------
Juice, canned commercial	----------	------	150–575 av. 375	------	---------
Turnip:					
White	0	12	600	------	12
Yellow	20	12	600	------	12
Turnip greens	10, 000	40	3, 000	------	120

See footnotes at end of table.

TABLE 1.—*Values selected as representative of the vitamin-A, vitamin-B_1, vitamin-C, vitamin-D, and riboflavin content of common foods*—Continued

Food material	Vitamin A	Vitamin B_1	Vitamin C	Vitamin D	Riboflavin vitamin G
	Units per 100 grams [1]				
	Int.	*Int.*[2]	*Int.*[3]	*Int.*	*Sherman* [4]
Walnuts:					
Black	130	110	----------	------	---------
English	100	150	----------	------	---------
Watercress	4,000	40	1,500	------	90
Watermelon	Trace	20	150	0	10
Wheat	Trace	180	0	------	35

[1] Where there are no values, data were not available for making estimates. 100 grams is approximately 3.5 ounces.

[2] International units of vitamin B_1 multiplied by 3 give micrograms of thiamin.

[3] International units of vitamin C multiplied by 0.05 give milligrams of ascorbic acid.

[4] For the calculations made in this table, the relation of 1 Sherman unit equivalent to 3.0 micrograms (0.003 milligrams) of riboflavin was used. Sherman units multiplied by 3 give micrograms of riboflavin.

*For vitamins A and D use values given on the container.

† The author suggests the following revisions for table 1: A value of 100 for the vitamin-A content of cottage cheese instead of 500, a value of 10 for the vitamin-C content of dried prunes instead of 50, and a value of 78 for the riboflavin content of jumbo and roasted peanuts.

SELECTING FOODS TO MEET VITAMIN REQUIREMENTS

In planning or assessing diets for adequacy in vitamin content, it is obviously necessary to have information as to the quantities of each of the vitamins needed in the daily diet. Suggested values for vitamins A, B_1, C, D, and riboflavin are summarized in table 2.[4]

At the present time considerable interest is being shown in studies to determine the requirement of the various vitamins known to be essential in the diet of man. The main problem has been the development of methods giving results that could be interpreted in relation to nutritional well-being. The first knowledge of the requirement of any vitamin came as a result of determining the quantity required to cure or prevent the disease associated with that vitamin. Such quantities have usually been referred to as minimum protective quantities. It soon became apparent that the quantity needed for normal nutrition was considerably in excess of the minimum protective quantity. As information and experience accumulated the aim has been to obtain values of vitamin requirements that apply more nearly to normal nutrition.

[4] See also the Table of Recommended Dietary Allowances prepared by the Committee on Food and Nutrition, National Research Council, May 1941, available through Nutrition Division, Federal Security Agency, Washington, D. C.

TABLE 2.—*Values suggested as expressive of the daily requirement for vitamins A, B_1, C, D, and riboflavin*[1]

Vitamin	For the average adult under average conditions			During pregnancy and lactation	For growing children and adolescents
	Absolute minimum	Adequate	Optimum		
A	2,000 I.U.	3,000 to 5,000 I.U.	6,000 to 8,000 I.U.	More	8,000 to 10,000 I.U.
B_1 (thiamin)	200 I.U. or 0.6 mg.	300 to 400 I.U. or 0.9 to 1.2 mg.	500 to 600 I.U. or 1.5 to 1.8 mg.	Several times allowance for average adult	Considerably more in proportion to their weight than adults
C (ascorbic acid)	20 to 25 mg. or 400 to 500 I.U.	40 to 60 mg. or 800 to 1,200 I.U.	80 mg. or 1,600 I.U.	Twice that for the average adult.	Only slightly less than that for adults.
D	Not known			800 I.U. suggested as adequate	300 to 400 I.U. suggested as adequate for protection against rickets; 675 I.U. suggested for optimum growth.
Riboflavin (vitamin G)	Approximately 600 Sherman-Bourquin units or 2 milligrams.				At least 400 Sherman-Bourquin units.

[1] Previously published. Munsell, Hazel E., Planning the day's diet for vitamin content. Journ. Amer. Dietetic Assoc., vol. 15, p. 639, October 1939.

In summarizing data on vitamin requirements, it seems desirable to give the quantities determined as minimum as well as those considered adequate. In some instances data have been obtained indicating that nutritional well-being is enhanced by a diet supplying quantities of a vitamin in excess of that considered adequate. Such quantities have been designated as optimum.

Studies to determine the requirement of the various vitamins are still in the preliminary stage. It is problematical whether the requirement of any vitamin can ever be expressed with precision. Many factors operate to influence the quantity of each that is needed. Data already at hand indicate that the requirements may vary from individual to individual according to sex, age, size, and activity, and vary in the same individual from day to day depending upon the physiological condition, activity, or environment.

The material offered in table 2 should be used with certain considerations in mind. With the exception of vitamin D the values for the requirement of each of the vitamins represent quantities that may be supplied readily by the use of natural foods. These quantities indicate the *daily* requirement of the *normal* individual with no allowance made for variation in the vitamin value in different foods or losses that may occur from cooking or other processes to which the food may be subjected.

There is no evidence of harm from the ingestion of vitamins as they occur in foods in quantities considerably in excess of those given as requirements. In planning diets the aim should be to provide foods that will supply at least as much and preferably more than the adequate allowance of each vitamin and several times this allowance in cases where there is indication of a greater need.

SCIENCE AND HUMAN PROSPECTS[1]

By Eliot Blackwelder
Stanford University

On facing the duty of preparing the customary presidential address for this year, I gave some thought to the question of what contribution I could best make. Having been for many years a field geologist and at times even an explorer, I might have gathered up the results of many local studies and generalized them. Being engaged more recently in studying desert physiography and the Pleistocene history of the western States, I might have chosen one of those subjects—and indeed they are well worth considering.

However, in such a fateful year as 1940, it seemed to me that the occasion called for a subject of greater importance and one that has a more direct relation to the welfare of this nation; and so I decided to ask your attention this evening to a subject that has long been one of my chief concerns—namely, education in science and its relation to the future welfare of humanity.

It seems to me that a teacher of geology, or indeed of any other science, should devote himself not only to giving his students information, and explaining processes and theories—however important those educational duties may be—but especially to training young people in the scientific way of thinking and helping them to acquire the scientific spirit. To my mind, that is his most important function.

Since geology is considered a science—albeit not one of the so-called exact sciences—and since we call ourselves scientists, it may be well to ask at this point, what, essentially, is science? In general terms the dictionaries say that it is knowledge established, organized, and systematic. To me, however, this concept is not adequate. In the words of the great French mathematician, Poincaré: "A collection of facts is no more a science than a heap of stones is a house." Verified knowledge is one element, organization and classification are necessary and so is the testing of hypotheses, but I cannot regard any of these

[1] Address as retiring president of The Geological Society of America, delivered at the annual meeting of the Society in Austin, Tex., December 26, 1940. Reprinted by permission from the Bulletin of The Geological Society of America, vol. 52, Mar. 1, 1941.

as the core of science. To me the basic thing about science is an attitude or habit of mind, a way of thinking which is characteristic of those entitled to be called scientists. If that is so, most subjects of human concern may be dealt with in a scientific way. The essential basic condition is freedom from bias and prejudice. The major objective of the scientist is truth, no matter how unpleasant it may be or how much discomfiture it may cause among those who hold cherished beliefs which happen, nevertheless, to be errors. Dr. Crapsey once remarked that: "Truth is a brand new virtue." And it may be added that as such it is not yet as widely sought and valued as it should be. It has been well said that "the purpose of science is understanding." This is only a modern version of the well-known admonition of King Solomon to "get understanding."

The scientific method is relatively new. As recently as four centuries ago it was a rarity even among the most learned thinkers of the time. Today it is used only incidentally by most of the people in even the most civilized countries. It is hardly an exaggeration to say that the majority of educated persons—even those with college degrees—do not really understand it. Often it is confused with invention or the mere cataloging and classifying of knowledge. Some years ago, in a nation-wide poll which was taken for the purpose of finding out who was popularly considered to be the greatest scientist in the United States, the choice fell upon Edison, the inventor. But inventions, however useful and ingenious, are only the outgrowth, the byproducts, of science. Although invention was originally a matter of mere cut-and-try experiment it now makes more and more use of science, until much of it is now highly scientific in the true sense. Even so, the one should not be confused with the other. Science is not invention. The purposes of scientists and inventors are fundamentally different, even when they use similar methods.

As for the majority of mankind, in the less-developed countries, their lives have scarcely been touched by science except in the form of some of its tangible products such as machines, the radio, or by the services of the sanitarian; and their understanding of science is hardly greater than was that of their ancestors a thousand years ago.

Even among the most cultured of civilized people some misunderstand science so completely that they think they disapprove of it and consider it dangerous. Not infrequently do we hear the ills of the world today blamed upon the advances of science, by which is evidently meant inventions such as dynamite, poison gas, or the airplane. Some writers have even called for a moratorium on scientific research, lest the dangers they ascribe to science overwhelm our civilization. But we do not abolish automobiles just because criminals use them in bank robberies and child snatching. On the contrary, it would

seem better to extend the scientific method to those fields of study which are not yet making the required progress. One might paraphrase a famous remark about democracy by saying: "The best cure for the evils of science is more science"—at least better and more widespread science.

The genuine scientist searches out the facts he requires, testing and evaluating them as he goes. He must try to discriminate the true from the false, and the trivial from the significant. His disciplined imagination, always at work even during the fact-gathering process, suggests explanations for the things observed—usually for the details and later, as the picture takes shape, for phenomena of wider scope. All these ideas must be impartially tested before they can be either accepted or rejected, just as an engineer determines by calculation the strength of the arches in a projected bridge, and for a similar reason. How high shall we appraise the value of the fortunate speculator who happens without much evidence to hit upon the right explanation far ahead of others, as compared with the patient investigator who carries a firm structure of fact and controlled theory with him all the way? The former has uses, but it is chiefly to the latter that steady scientific progress is due. Loose speculation is an ingrained habit of humanity, but the careful scientist realizes that many problems are now insoluble because the necessary data are not yet obtainable. He will, therefore, restrain his fancy, devoting his efforts to objectives that are within his reach, content to leave to his better-informed successors those other questions which are not yet ripe for consideration.

The critical testing of ideas is a habit difficult for the average human being to adopt. An original idea is a brain child and tends to be jealously cherished as such. To expose it to the cold light of reason takes a sort of Spartan courage that is too often undeveloped and yet is one of the essential attributes of anyone who aspires to be called a real scientist. To be merely logical with facts selected for a purpose is much easier than to divest oneself of bias. Steadfast courage and a renunciation of false pride are required in the search for opposing rather than supporting evidence.

The unrealized assumptions hidden in his theory are the sunken rocks on which the ship of many a hopeful scientist is wrecked. Our literature affords examples without number, especially in the earlier times. Geologists will find a good illustration even in the writings of that thoughtful old Scot who is regarded as the founder of their science—James Hutton. Writing about the granite boulders from Mont Blanc that are sprinkled over the slopes of the Jura Mountains near Geneva, he concluded that the Rhone River must have excavated its valley after they were deposited. The erroneous as-

sumption, hidden in his mind and unrecognized, was that only streams could have moved the boulders, and he knew that streams cannot flow uphill. He overlooked the glaciers, although it is evident that he already knew something of their power and habits. Perhaps he assumed that those he saw around Mont Blanc had never been much larger than they were in his day.

Failing to understand what the real scientist must be and what the essentials of science are, part of the public today is led to accept as science various elaborations of intuition, speculation, and fancy, such as were much more widely current a few centuries ago. To the practitioners of this pseudo science, David Starr Jordan (1924), in a humorous paper, once gave the name "Sciosophists." The term, he explained in mock seriousness, comes from two Greek words, *skios* meaning shadow, and *sophos* meaning wisdom, or in short "the shadow of wisdom." Sciosophists, he said, are happily free from the ordinary limitations of science for they are not hindered by the need of evidence. To them one idea is as good as another, and so why go through the laborious process of examining facts, searching out all the evidence, and testing each explanation before accepting it? A glittering and imposing structure can be built up with ease by a sciosophist out of many such unverified suppositions; but, of course, Jordan scarcely needed to say that it is as vulnerable to critical analysis as a child's tower of blocks is to a touch of the hand. It is regrettable, but in a free country perhaps unpreventable, that the cloak of science should be donned and worn by faith healers and other mystics who have no comprehension of the meaning of the term. As a result, however, it is hardly surprising that part of the general public has a rather confused impression about science, when it reads serious accounts of such absurdities as a "science of astrology," "the science of phrenology," and many others.

That the scientific method had its beginning in the ancient Greek and probably even earlier civilizations is clear enough, but it was displayed by only a few of the philosophers of that era and not consistently even by that few. This is all the more strange in view of the fact that the art of reasoning—logic—was highly cultivated by the Greeks. True, men like Anaxagoras at Athens had many sound ideas and employed the scientific method to a notable extent, but at the same time they entertained, as firm beliefs, some notions that would now bring a laugh to any schoolboy.

If one examines the writings of the founders of ancient Greek science in the sixth century B. C.—men like Thales and Anaximander—he finds that many of their opinions were mere suppositions, elaborated and bolstered with such support as labored argument and ingenuity of words could give. These men were the precursors of

modern scientists but can hardly be called scientists themselves. No true scientist would have seriously put forth as a conclusion so fantastic and wholly unverified a notion as the great Aristotle's dictum that earthquakes are due to the surging of the wind through caverns in the earth. Even allowing for the inaccuracies of translation from the Greek, one can find only the slenderest evidence to support this opinion. It was a result of pure speculation upon a subject about which the author had not even the most elementary knowledge. Yet it was quoted with approval for 20 centuries. This is all the more inexcusable because a considerable body of definite information about earthquakes was available in the Greek world of Aristotle's day, and there were many pertinent observations on geology that could easily have been made in that epoch, even without modern instruments, if serious attention had been devoted to the problems.

In its early stages the cultivation of science was often too largely a contest between champions of rival theories. In ancient Greece the celebrated master gathered about him a group of disciples who too often came to regard his pronouncements as infallible. In the school of such a man as Pythagoras of Sicily, to quote the leader was sufficient to settle any disputed point. The ideas of the master thus became dogmas and took on a kind of sanctity.

It must be admitted that dogma has been the fashion of the past. For millions of the earth's inhabitants it still remains so. Today we see the current of progress being reversed in the despot-ridden countries of Europe, where the privilege of freely drawing conclusions from evidence is being restricted and the blind acceptance of official dogma is exalted as a duty, if not a necessity.

Even in the last century or two the history of science was marred by many a bitter controversy between rival leaders and their followers over theories. A theory was defended like a home citadel, and doubters were considered enemies actuated by the darkest of motives. Among such bickerings there was by contrast the magnanimity of Charles Darwin who said, regarding the storm of criticism that raged after the publication of "The Origin of Species," "If my book cannot stand the bombardment, why then let it go down and be forgotten."

Fortunately, rancorous disputes have nowadays largely ceased to afflict the relations of real scientists. Yet there is still far too much of that spirit in the world at large. It has been well said that "Most men think with their emotions rather than their intellects." The ancient method of verbal combat is still employed in our law courts and legislative halls. Each participant adheres to his thesis. Search is then made for evidence to support it and at the same time to

refute its opponents. An equal effort is made to suppress or depreciate any facts that may prove to be embarrassingly adverse.

The debating society may be a good place to train lawyers, but the partisan attitude of "win the argument and confound the opponent" is an unhealthy state of mind for a young scientist. Indeed, he can never become a true scientist until he outgrows that mental attitude. Rather he should cling to the advice of that wise old Quaker, William Penn: "In every debate, let truth be thy aim, not victory." Perhaps it is our sporting instinct, derived, it may be, from our age-long struggles against each other, that makes us usually more interested in winning a contest than in finding the truth.

By those who have not considered the matter thoroughly, scientists are often adversely criticized for devoting so much of their energy to problems that seem to lead to nothing of any human value. No doubt there is considerable merit in this charge. But we shall never know to what extent it is justified, because we can only guess what kind of knowledge and what kind of understanding may become useful in the future. The history of science is full of examples supporting this statement. Our huge electric motor industry grew out of the simple discovery by Faraday that when a magnet was moved in a loop of wire an electric current was generated in the wire. Why should the knowledge of that bare fact have been of much value, and why should the public have been impressed at the time? In fact, it was not. Only a few men of science gave it some attention, as revealing a new principle—that of electromagnetic induction. Similarly, the oil industry of Texas has been greatly aided by the intelligent combining of many bits of scientific information no one of which by itself has much commercial value—such items as undulations in strata, earth vibrations, soil analyses, and Foraminifera in drill-hole samples.

Although the gathering of facts cannot in itself develop a science, yet facts we must have, in infinite number and variety, even though they are only the bricks to be used by the builder. The mere multiplication of facts, the piling up of observations closely similar to hundreds of others, is properly regarded as of less value than the search for explanations, principles, and laws. While the layman thinks of Major Powell as the intrepid explorer of the Colorado River and its Grand Canyon, discovering, even at the risk of death, the wild beauty of its scenery and the details of its geologic section, it is fitting that geologists should honor him even more for his clear exposition of the principles of the base level of stream erosion and the antecedent river.

In view of the fact, already mentioned, that we can seldom foresee what utility any scientific fact or principle will eventually have, we

cannot afford to neglect any aspect of science. Discoveries in one field often release obstructions that have held back progress in other branches of science, and thus permit further advances. On the other hand, by regimenting scientific work and even opinion, along with all other phases of life, for their own immediate purposes, modern tyrants are violating this principle. This they can do with some measure of success for a short time, but eventually their countries will almost surely suffer a degeneration of science, and therefore of the civilization which is based upon it.

Along with the increasing complexity of modern life there has grown up an urgent need for the scientific expert. The demand is being met by many persons who are real scientists but unfortunately by others who do not deserve the name. On that score Dean Roscoe Pound lately said in sarcastic vein that "the administrator is not appointed to office because he is an expert but he is an expert because he has been appointed." We all know of cases that fit this satire, but in all seriousness we may trust that they are not numerous and that they are decreasing.

Since the public must depend on its experts, it is essential that it should be well justified in placing confidence in them, to the end that such respect will endure. That puts a heavy responsibility upon the individual expert. As Grover Cleveland once said, "a public office is a public trust," no less so should any degree of leadership in science be regarded as a public trust; and so the expert scientist is under great obligation to deserve the confidence of the public. His intellectual honesty will need to be outstanding and unwavering. Today, in this country, the scientist has already won such esteem to a large degree, although he is compromised and discredited now and then by the shortcomings of the less conscientious and careful of his colleagues. Unfortunately, too, it is among the latter that the most vocal types are apt to appear, and it is they who often attract the most public attention. Perhaps it is expecting too much of man, as we know him, to hope that a time will some day arrive when our most influential leaders will be persons who have the true scientific spirit and have been trained expressly for the work they are to do, as humble in the face of their own limitations as they are wise and honest.

Many years ago a former president of our Society, R. A. Daly, speaking informally as a visitor to one of my classes, advised the boys to "think to scale." It would be hard indeed to pack more meaning into three words. The person who thinks to scale sees the relative value of each fact he uses and of each objective before him. He can then economize his time by confining his attention chiefly to the important and the significant problems. On that point the wisest

of the Roman emperors, Marcus Aurelius, is said to have remarked that "Every man is worth just so much as the things are worth to which he devotes his earnest efforts." It might be somewhat disquieting to many of us if we should measure ourselves by that principle.

More than three centuries ago Sir Francis Bacon urged the application of the scientific method, as he then conceived it, to human affairs and problems in general, but we are still far short of having adopted his advice, although all our experience since his day confirms its value.

The greatest progress has been made thus far in the physical sciences and scarcely less in the biological. The scientific method and attitude of mind also pervade to a very large degree the related professions of engineering and medicine. Engineering and invention, based in increasing measure upon science and pursued largely in the scientific spirit, have given us nearly all our modern transport and communication facilities, our great water control and power devices, our vast numbers of useful and convenient new materials such as rayon, plastics, alloy metals, and other benefits too well known and too numerous to mention. But for the application of medical science we should be decimated not only by typhoid, tuberculosis, and smallpox, but also by yellow fever, cholera, and even the plague. Were it not for the deficiency of science in politics, statecraft, and ethics we might not find ourselves today threatened by the plague of military despotism, which is more deadly in its modern form than any pestilence. We have used the scientific method in engineering and medicine for a century and have found it good—far more effective than the old ways of speculation or of trial-and-error. In spite of the difficulties involved, why not then extend it to other fields? Is there any reason to suppose it will not bring great improvement there also?

In such fields of study as economics and sociology, the complex and fluid nature of the basic data that must be used and the influence of human prejudice, which closely touches these subjects, have greatly impeded their emergence from speculative philosophy and their rise toward the scientific level. In addition they need a more general adoption of the scientific attitude and method. Why not apply these to human affairs, subdue the emotional considerations, and brush away the cherished errors of the past? Then we should be able to move more rapidly toward a real understanding of principles, for we are justified in believing that such principles do exist.

In ethics, which is in some respects the most important of all subjects of human inquiry, we have made no great progess beyond the Greeks of Aristotle's day; and most of them were, except in

mathematical studies, philosophers rather than scientists. Even today the study of human conduct is but slowly emerging from its age-long status as an appendage of religion. Would it not bring fruitful results to study ethics in the same scientific spirit that already pervades such a field of research as physiology? Without a firmly based and widely accepted science of ethics, the other natural sciences alone may lead us eventually to ruin for want of adequate control. Under the direction of the engineer, dynamite is an effective aid in construction and promotes industrial progress; but in the hands of the criminal it means murder and destruction. The difference is only one of ethics.

To have science flourish, there must be complete freedom of inquiry and discussion. The beneficial influence of such freedom is indicated by the extraordinary development of philosophy and the sciences among the Greeks in the fourth to the sixth centuries B. C., in the Germany of the nineteenth century, and in modern America. Scholars properly insist on this necessity and guard their hard-earned right to intellectual liberty; nor is this freedom of research so firmly held but that it takes a little defending all the while from the bigots who would close to discussion certain trends of thought of which they chance to disapprove.

But if the scientist is to deserve and therefore keep his freedom, even in a democracy, he should be equally scrupulous about his own responsibility to the public. He has no right to claim on the one hand immunity from restraint and on the other license to be unreliable. It is the few irresponsible members of our profession who endanger our freedom of expression, for it is their words that tend to discredit the very science to which they are nominally attached and thus bring all science into disrepute.

One of the best indicators of the scientific maturity of a nation is the standing accorded scientists in their own communities. In Greece science and philosophy flourished not only because they were free, but because they brought honor and even wealth to those who distinguished themselves in scholarship. In Germany 40 years ago the great scientist, like Helmholtz, was appointed a Geheimrat and on the whole stood higher in the social scale than the banker or the industrial magnate. In our own country we are lately beginning to appreciate our thinkers, but their value to the world is not widely comprehended, nor are we very discriminating in recognizing them. We are apt to rate too highly the man who makes a spectacular but very definite and easily apprehended discovery, as compared with another who slowly develops an idea or principle which in time unlocks for us another room of progress.

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Jefferson, Franklin, and other founders of our American Union fully realized that a well-informed people was essential to the success of the republic. Although a lover of freedom, Goethe understood the difficulty of making a democracy succeed, remarking that "the trouble with democracy is that it has to wait for an enlightened public opinion." More pessimistic commentators, like Disraeli, were confident that the experiment could end only in failure, because they believed that even the best popular education that was practically attainable would be inadequate.

A system of education, to be good, must be suited to its time in history. The boys of ancient Persia were taught "to ride and to shoot and to speak the truth." In their day, nearly 3,000 years ago, that was education enough, but now it would be of little avail, although the last item (speak the truth) has eternal value.

If we were willing to accept the Nazi plan of society we should need only a small highly educated upper caste. The rest of the people would be given only training and indoctrination. But if we want freedom and the so-called democratic way of life, then we need the most widespread and effective education that our mental equipment will permit. In our own system, a few wise leaders would be helpless in the face of a grossly ignorant populace, swayed chiefly by its emotions and prejudices. Too often this has been true in democracies thus far, and in America it is still a dangerous factor. So I conclude that we must have, as soon as we can provide it, far better and more extensive education, and a general adoption of the scientific attitude of mind. Is that a large order? It surely is—perhaps too much to expect—but it may well be the price of our liberty and the survival of the American type of civilization.

Hitler is quoted as having said that no people is capable of governing itself or even of planning its own affairs. If the majority of the people are to be kept in ignorance, he is doubtless right. As our life becomes more complex our problems become more difficult. To solve them badly may mean disaster. To solve them well requires adequate knowledge and especially clear thinking. Bias and prejudice are liabilities or handicaps that we cannot well afford and hence should try by all means to reduce. If, in a republic, we are to have affairs well handled, we must rear millions of capable unbiased persons to make those varied problems their life concerns. That, it seems to me, demands the scientific attitude of mind and an efficient system of education expressly devised for that purpose; for it is not something which we gain by inheritance or in the common experiences of life.

To insure a well-informed and intelligent people is a most difficult task. History affords no good example of such a nation. It is by

no means certain that it is even possible. The eugenicists will properly assert that their advice must be followed, and no doubt there is some hope in their principles and plans; but beyond that it seems evident that education is our best chance. It means educating more people and educating most of them longer—perhaps continuously throughout life. Most important of all, it means educating them far more wisely and efficiently. As a scientist I am perhaps biased in believing that the most important element in this education is the scientific attitude of mind. That does not mean that every person must become a scientist, but that he must acquire the habit of thinking as a scientist. It means that the great majority should understand what science is, what it stands for, and its value to society. They should then be able to recognize the true scientist and distinguish him from the sciosophist or the imposter. It will also enhance their capacity to judge the merits of their leaders and the general issues of the day.

Having harped at length on the importance of science, I must ask you not to misunderstand me as implying that science is all we need. It is no panacea for our troubles. Indeed, if we were exclusively scientific we should not be human at all. There are other things that are also necessary—love, art, imagination, intuition, loyalty, poetry, and many others. I merely emphasize the opinion that science is one of the most indispensable factors in civilization. We must become more scientific and especially more widely scientific.

To say that one vital function of society is more important than another is as pointless as to say that the lungs are more important than the heart. We may, however, be sure that effective education is one of the indispensable concerns of a free civilized nation. In the opinion of Dr. Copeland (1928) "education is incomparably the most important function of society." Without it the state could not endure for even a century, for in no other way can the long, slowly won progress of the past be effectively transmitted. Good education is one of the greatest means of national advancement. Poor education insures the decline of a people and even their disappearance as a nation.

Many of the ablest thinkers in the past, from Plato down to our own day, have felt sure that democracy was an unworkable plan. Much as I hope that they were mistaken, I should feel constrained to agree with them if I did not have some grounds for hoping that we can devise and continually improve a process of education adequate for the requirements of the country; but it will need to be much better than anything we have had thus far. This hope is encouraged by the view of so experienced an educator as ex-President Morgan of

Antioch College, who has said that "results as revolutionary are possible in education as in engineering, and they are even more necessary."

Conditions in our schools and even in our colleges and universities today are far less satisfactory than they should be in view of our acute need of the best education we can provide. As recently remarked by Professor Curtis (1939):

> Even in this so-called scientific age we find, among our high-school, college, and university graduates, many who believe nothing definite and have no convictions, while many others will believe anything, no matter how fantastic * * * there is little difference between many college graduates and those who have not gone beyond the eighth grade, insofar as their mental attitudes or judgments in the fields of science are concerned.

This he is inclined to ascribe partly to the fact that many teachers, as well as students, have had little or no training in science and partly to the type of teaching that is all too prevalent, especially in our lower schools. Too much of it is dogmatic, and the student is not trained to think for himself. There is far too much emphasis upon the learning of facts, on the mistaken supposition that knowledge, as distinguished from understanding, is the chief object of schooling.

Since in order to progress we must constantly improve our education, we shall have to have more teachers, especially better and wiser teachers, and teachers who are not only competent to train youth but who are allowed to utilize their competence in teaching, under a minimum of administrative control. In my opinion no mature teacher who needs to be told by a principal or dean how to teach deserves to be employed as a teacher. There has grown up in recent years a widespread tendency to overstress the importance of teaching methods and to give school executives wide powers of direction over the daily work of the individual teacher. Such practice overlooks the fact that good teaching is a matter of individuality, that the teacher to be successful must be a true scholar, and that scholars cannot be regimented. Also, our system has always been less effective than it should be, because we have left so much of the education of our rising generation to relatively inexperienced young persons. This seems almost as shortsighted, and in the long run as likely to prove disastrous to the Nation, as to leave our military defense largely to young recruits. The only apparent advantage to this is that it is less expensive than the alternative; but the cheapest system may prove in time to be the least economical.

At this point it may be asked what results we can fairly expect from such improvements in our educational arrangements in the next decade or century. The experienced scientist will understand that sound improvement in human affairs will come only by evolution and after cautious experiments on a small scale rather than by sudden revolutionary changes on a large scale.

One of our greatest dangers lies in the impatience of many people to gain great results quickly. This is natural enough, in view of the brevity of our individual lives. But it is inconsistent with the principles which govern all life. We are a part of Nature and, however much we may seem to influence natural processes, there is every reason to believe that we are in fact and on the longer view controlled by Nature. Whether we like it or not, slow evolution is Nature's way. And so we can hardly hope to elaborate some theoretical new scheme of social or economic organization, put it into practice on a national or world-wide scale in a few years, and have any reasonable prospect of success. Hidden faults and weaknesses are likely to cause failure, and that in turn may exhaust for decades even the healthy impulse toward improvement. The fascination that these schemes have for our youth doubtless has a complex cause, but it may well be due in part to the faulty character of our current education, which has not given them the advantages of the scientific viewpoint. Again, as Daly said, they should learn to "think to scale."

However difficult it may be to forecast future trends more than a few years ahead, the geologist can hardly be expected to overlook the longer view; and so I may now raise a few questions about what may be in store for humanity in another epoch—not a matter of centuries but probably of tens or even hundreds of thousands of years.

There are many who expect that man will make continuous progress toward higher and better things, becoming in the course of time so much wiser, more sensible, and reasonable that the world's life will be vastly more happy than it has ever been in the past. War, sickness, and poverty would then be abolished. Cruelty, hate, and injustice would become obsolete, and we should be living in a sort of Golden Age the like of which we have never even approached. That is a beautiful vision to contemplate, especially in these dark times.

The lessons of historical paleontology may throw a beam of light ahead on this speculation, for of course it is no more than that. As we look back over the history of man we find evidence of great cultural progress since the time of the primitive cave man, who made crude stone implements but lived in isolated families competing with the wild beasts of the day for such food as could be found or seized. He was indeed only one of the beasts, and it is hard to point out more than a few respects in which he was superior to them. Did the early Stone Age men gradually develop, by slow practice and learning, into modern man? We do not know, but there is little reason to suppose so. All that we know today of human paleontology indicates that what we loosely refer to as man comprised a group of at least five and probably eight or more distinct animal species which are generally grouped by zoologists in several genera. These

may have originated in various parts of the world, each lived many tens of thousands of years, and then with one exception all became extinct. At certain times two or more such species may have coexisted, although probably in different regions. Perhaps they eventually killed off each other, just as the white race in historic times has exterminated the Tasmanians and certain other primitive tribes. But today only one species survives, and he has apparently had the field all to himself since the middle of the last glacial epoch, or about 30,000–50,000 years ago, according to current estimates. Each of these species appears to have been as distinct from the others as species and genera of animals usually are.

There is nothing to indicate that the very primitive *Sinanthropus* made much progress in culture during his long career in China. He learned to use fire—probably to make it—and to fashion a few simple tools of stone and bone; but that seems to have marked the limit of his inventive capacity. For shelter and safety from attack he seems to have crept into caves, like many another beast.

Neanderthal man, generally placed in the genus *Homo*, shows evidence of a distinctly higher culture. He made more varied and better tools of chipped flint, of wood, bone, and other materials ready to his hand. But with a brain which appears to have been inferior, even his long career as a species seems not to have sufficed for him to invent pottery, polished or ground stone tools, to learn to domesticate and use other animals rather than to hunt them, or to grow crops, not to mention building houses or using metals. Apparently he had some ideas about spirits and a future life, for he buried his dead with some care and placed in their graves some of their ornaments and weapons; but we have no evidence that he developed any art of drawing or sculpture, and none of his tools were finely wrought. There is evidence of only slight progress during the long age through which he lived, and at his best his cultural level was distinctly lower than that of the most primitive savages now known to anthropologists.

How these various species of men came into existence is unknown and may well remain so. But there is nothing to suggest that their origin differed in any way from that of the other mammals. To suppose that it did would be gratuitous speculation. Indeed, had it not been for the achievements of the latest of these species, the Hominidae would never have been entitled to special notice as anything more than somewhat peculiar mammals.

From biological friends whom I have consulted, I learn that they are not yet agreed upon the question of how a new species originates. In fact there is some difference of opinion as to just what constitutes a species, as contrasted with a race, a variety, or even a genus. While

waiting for the biologists to work out these problems, we may use the term "species" a bit vaguely in its current meaning, and we may tentatively adopt the now preponderant view that new species originate not by gradual imperceptible changes but by sudden mutations, either extensive enough to produce a distinct species at once or occurring in series which eventually culminate in full specific status.

However any new species actually originated, its parental species doubtless continued to exist for a time without much change. The new kind expanded in numbers and, if more effective, eventually overran and exterminated the older one. It then went on living without important physical change until it was in turn crowded out by more efficient animals or until it succumbed to other adverse factors in its environment.

Have we any reason to suppose that *Homo sapiens* is not subject to the same process or that his fate will not be similar? He differed from earlier species of men very slightly in physical form and structure. His achievements and the shapes of his crania suggest that he possessed, from the outset, not only a larger but probably also a distinctly better brain, which has enabled him to learn more extensively, to devise complicated languages, and eventually to develop what we now call civilization. This progress seems to have gone forward on a steadily rising curve. For perhaps 20,000 years *Homo sapiens* was only a savage, a wandering hunter. In the next 5,000 years or more he advanced locally to the status of a shepherd and even a village farmer. In another 3,000 years he learned to extract and use metals, form city states and even nations, and become skillful in many of the finer arts. Accelerated advance in the next 1,000 years lead to books, commerce, literature, and philosophy. The last century or two has witnessed a rapidity of material progress in communication and far-flung organization that exceeds anything previously known; and with it has come much growth in ideas and in the complexity of economic and social arrangements. Are we justified in assuming from the contemplation of that curve that it will continue to rise indefinitely, and at a similar rate? Is there in all geologic or human history any precedent for that? Other animal species of the past have followed career curves that involved a rise, culmination, and decline. We have seen the same law controlling the nations and even races of humanity. Will our own species also reach its climax and then deteriorate? And if that happens, how and when will it occur? As yet we have but little basis for answers to such questions.

In contrast to his progress in ways and ideas, *Homo sapiens* seems to have undergone only slight physical changes, even in the estimated 30,000 years of which some records have come down to us. Anatomically there seems to be no evidence whatever of any progress—no

increase in cranial capacity, probably no appreciable change in brain anatomy. In the last 3,000 years, in which some evidence is available, there is no sign of any improvement in native intelligence. Man's actions are still governed more by his emotions and subconscious mental elements than by his intellect. His savage instincts, that we like to think began to be conquered thousands of years ago, are still present beneath the surface and reappear at unexpected intervals even in civilized man. Among the more backward modern races of humanity they have scarcely changed.

In short, our surviving species of *Homo*, being one of the mammals, is probably as definitely limited in his possibilities as are the other species of that class. Just as we do not expect a dog to learn algebra, although he can learn to open a door, so we probably ought not to expect more from present-day man than his brain is capable of attaining. As Hawkins (1930), the English paleontologist, sees it: "Our mental capacity is a specific character." If this is the truth of the matter, it may be over-optimistic to expect our own species to rise far above his present stage of mentality. Notable improvement along lines already established, and a raising of the other two-thirds of the earth's population to or above the level of the present civilized minority, may well take place over the centuries and thousands of years yet remaining in the expectable future life of this species. His contribution to biological progress will then have been made, and, if history is to repeat itself, he will then be ready for conquest, if not extermination, by some other type of being, perhaps some new species of the Hominidae that has more innate capacity for progress.

Whence may such a higher species originate? Will it be an outgrowth of the most highly civilized nations of today? The general testimony of history suggests the contrary. The ancestral mammals did not spring from the most advanced dinosaurs of the Mesozoic era. Man and the great apes are traced back, not to the large specialized mammals of Eocene times, but to primitive generalized animals related to the humble insectivores. The extraordinarily successful Mongol dynasty of the Middle Ages arose not from the cultivated Chinese of Nanking, but from a tribe of barbaric nomads of the steppes. Likewise the most civilized nations of modern Europe did not spring from the Romans of Caesar's day but from the forest barbarians around the Baltic. Perhaps, therefore, the progenitors of the newer and better man will appear unnoticed in some remote and backward corner of the world, where they can develop in obscurity, while the well-known modern races of *Homo sapiens* contend with each other for a transient supremacy.

Just as it would have been difficult for even a most intelligent trilobite to imagine the fish, which was destined to drive him from

the scene, so it is not easy for us to forecast the nature and potentialities of that new species of *Homo* which may appear in the distant future, unless indeed our genus itself has by that time run its course and it is not destined to offer the world anything further. It is of little consequence whether such a new species may have smaller teeth, a skin less hairy, or taller stature. The only way in which he is likely to outstrip *Homo sapiens* effectively is in the quality of his brain. Will he be able to absorb knowledge more rapidly and remember it better? Will his imagination be keener; will he reason out his problems more effectively; and, above all, will his life and conduct be controlled by his intellect rather than by his feelings? If so, he may be able to take knowledge in larger doses, profit more by the stored-up experience of others, instead of merely his own, and by the lessons of history. He should be far more educable than any earlier species in the family.

It may be objected that these speculations are hardly optimistic, that they do not present a hopeful picture, and that they do not necessarily envisage continued progress toward a far higher and better human world. To this I must reply that a scientist is under no obligation to be an optimist. His only concern must be to approach nearer to the truth. If the truth offers hope, we may rejoice. If it fails to do so, we are not thereby justified in denying or even ignoring it. As King Solomon long ago advised, let us get understanding, and by so doing we may reach a serenity of outlook that will fit us better to play a worthy part in the great drama of human evolution.

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ICELAND, LAND OF FROST AND FIRE[1]

By VIGFUS EINARSSON
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[With 12 plates]

Remote from all other countries, in the middle of the Atlantic Ocean, a stepping stone between the New and Old World, lies Iceland. It is the largest island in Europe after Britain, having an area of 40,000 square miles.

Iceland is a very mountainous country, consisting of basalt lava and other volcanic rock, with, however, a large area of lowlands, especially in the south and the southwest. Otherwise there is very little lowland, except at the heads of the fjords and in the great many valleys which stretch from the numerous fjords and bays up into the highlands. Except for some rounded hills and shallow depressions, the central part of the country is an unbroken plateau, 1,100 to 2,600 feet high. In the interior, a great deal of the territory, especially the higher mountains, is covered with a cap of eternal snow.

Iceland is the most volcanic country in the world, and is, perhaps, most widely known for her volcanoes. Volcanic signs can be seen everywhere. Not only the mountains but great plains are covered with lava, often like a furious sea which has suddenly become stilled. This is something more than a simile, because the lava was once a roaring current of boiling rock. Over a hundred eruptions have been recorded since the country was first inhabited. In later years, however, volcanic eruptions have not been frequent, and most of them have taken place in the center of the country far from human habitation.

The most famous of all volcanoes in Iceland is Hekla, a familiar name in every country. In former times this mountain was considered unmistakable proof of the existence of Hell. For several centuries people refrained from climbing Mount Hekla because it was believed to be the chimney of the dark abode underneath, but during later years it has become quite popular. A return trip to the

[1] Reprinted by permission from the Canadian Geographical Journal, vol. 21, No. 4, October 1940.

top of Hekla, with a neighboring farm as a starting point, takes 10 to 12 hours. The view from the top is magnificent and well worth the somewhat strenuous trip, which is accomplished partly by the aid of ponies.

In Iceland there are many glaciers under which are volcanic craters in various places, as for instance, in the western area of Vatnajokull, which, in recent years, has commanded attention on account of volcanic eruptions. A number of Icelandic and foreign scientists have climbed the glacier in order to investigate this peculiar phenomenon of ice and fire. It is fantastic to visualize these two opposing forces in conflict, fire breaking its way through hundreds of feet of solid ice.

Hot springs and geysers are to be found all over the country, even in the rivers, on the sea bed, and under the glaciers. The most famous of all the hot springs is the Great Geysir about 80 miles from Reykjavik; from it spouting springs all over the world have derived their name. After having witnessed an eruption of the Great Geysir which lasted for 20 minutes, a Scottish captain remarked: "This power would have sailed half a dozen *Queen Mary's* right across the Atlantic." This unbroken column of scalding water and steam that rises from 160 to 180 feet up into the air is impressive and affords a spectacle never to be forgotten. The internal heat of the earth is a tremendous source of power. During recent years the Icelanders have been busy harnessing this heat and power. This is done chiefly by heating houses, buildings, swimming basins, and greenhouses. Not only are a great number of individual farms heated by the thermal springs, but certain public buildings as well, such as the larger country schools. It is of special interest for the traveler to note that many of these country schools are used as hotels during the summer season. In these places one can have outdoor and indoor swimming in warm water. The houses, in a considerable part of Reykjavik, are already heated by the thermal springs near the city, and we have reason to hope that a heating system of this kind will cover the entire city within a few months. After that no chimneys will be built in Reykjavik. The greenhouses, supplied with natural heat, are already busy procuring flowers as well as tropical fruit.

There are numerous rivers in Iceland and some of them have great volumes of water. Most of the larger ones have their origin under the glaciers and are of an opaque grayish color, on account of the glacial clay. Others rising from springs are crystal clear. Most of the rivers are now spanned with bridges, but one can still imagine what it meant to ford them on ponies.

These huge rivers, rapid and powerful, sometimes run peacefully, although with a hidden strength, over fertile plains; sometimes

plunge in tremendous falls, thundering on their way, and where the rivers drop down from the highlands, magnificent and beautiful waterfalls are formed. The most remarkable of these are Dettifoss in the north and Gullfoss in the south.

The water power in the country is enourmous, and year by year it is being more and more utilized. At present it is giving light and heat to thousands of homes in Iceland. But the rivers in Iceland provide another asset; in a number of them the salmon are abundant, as are the trout in the many lakes in different parts of the country.

The lava fields of Iceland are numerous and extensive, especially in the uninhabited part of the country, the most remarkable of these being Odàoahraun, the largest lava field in the world.

Iceland has often been called "the land of contrasts" and it justly deserves the name. This is a land where the snow-white caps of the mountains cover the intense fire beneath, where you can take a bath in hot-spring water out in the open during the severe part of the winter; the inhabited valleys and plains are friendly, inviting, and charming, the lava deserts desolate, barren and awe-inspiring. Beautiful lakes and rivers winding through green pastures and fertile meadows with their gushing geysers are a sharp contrast to the sparkling glaciers, those fields of snow and ice, where no birds sing, and where nature is dead and silent except when the wind sweeps over the white desert.

THE CLIMATE

The name of the country and its geographical situation have given rise to the prevalent erroneous ideas about the island. Fortunately, however, there is very little similarity between the name and the country itself.

The climate of Iceland is a maritime climate: not particularly warm in summer and not very cold in winter. As for the temperature, it is interesting to note that the mean temperature in January in Reykjavik, the capital, is about 30° F. The mean summer temperature is 52° F. The mean temperature of the whole year is 39° F., which is similar to Quebec. In Reykjavik we very seldom have snow, and on the lowlands snow rarely lies for long; on the mountains, however, it lies deep, making ideal conditions for winter sports.

THE POPULATION

And now, who are the people who inhabit this "land of frost and fire" as Iceland is sometimes called?

The people of Iceland are descendants of Scandinavian vikings who were full of vitality, eager in exploiting new countries and

seeking freedom as Leifur the Lucky, the Icelander who discovered America.

Iceland was colonized mainly by Norse vikings, who wanted to throw off the political yoke of Harald the Fairhaired of Norway. But a considerable part of the early settlers came from the British Isles, principally from Scotland and Ireland. The Icelanders are therefore a Scandinavian people with a mixture of Celtic blood.

Hrafna-Flóki was the first viking who intended to settle down in Iceland, but he left the country after a short stay, somewhat disappointed, as due to lack of foresight he gathered no hay for the sheep he had brought with him and therefore lost them all. Before he left the country he climbed a high mountain and saw a firth full of ice. This gave him the idea of giving the country the uninviting and rather misleading name it bears.

In the year 874 the first settler of Iceland, Ingölfur Arnarson, landed on the south coast of the country. Three years later he built his homestead where Reykjavik now stands. Reykjavik claims the distinction of being specially selected by the gods themselves to become the leading place of the country. According to the tradition, Ingölfur, when he sighted land, threw overboard his high seat pillars, declaring that he would settle down where the gods deigned to have them driven ashore. After a 3-year search he found them where is now the harbor of Reykjavik.

Sixty years after the settlement of Ingölfur the population was about 50,000; these self-willed vikings made their homes here, becoming a nation of farmers and creating their own history and culture.

In the summer of 930 the people established a code of laws. This legislative assembly, the Althing, the oldest parliament in the world, used to gather every summer at a place called Thingvellir.

In the year 1000 the Christian faith was adopted by law. In the same year Leifur, called the Lucky, discovered America, which he called Vinland. In commemoration of this event, the Congress of the United States of America presented Iceland with an impressive statue of Leifur the Lucky at the one-thousandth anniversary of the Icelandic Parliament in 1930.

THE LANGUAGE

Icelandic, the language of Iceland has remained pure and practically unchanged since the time when it was the common tongue of all northern people. Consequently, it might be called the mother tongue of the Scandinavian languages; a great many words in the English language are derived from this same source.

In Iceland there are no dialects, thanks to the national literature the Icelanders created long before any such thing was known in other parts of northern Europe.

Early in the twelfth century the Icelanders began to write their laws and the history of their country on parchment, which was followed by the writing of the famous Icelandic "Sagas."

POLITICAL RELATIONS

In the thirteenth and fourteenth centuries, through changes in political relations, Iceland became united first with Norway and later with Denmark.

The loss of political freedom, epidemics, and widespread poverty and hardships for many years caused the population to diminish to about one-third of what it was at the time of the republic. But during the last few decades the Icelandic people seem to have taken on new life. In 1918, after a long and strenuous political struggle, Iceland became an independent and sovereign state in personal union with Denmark through a common king. Since the restoration of the power of administration, a steady and far-reaching change has taken place in the mode of living and general conditions in the country.

FISHING, AGRICULTURE, INDUSTRY, TRADE

The Icelandic nation is one of the smallest nations in the world (population about 120,000), but its influence in the world trade is felt far beyond what one might expect.

The greatest factor in Iceland's economic life is the fisheries. The sea around the country is enormously rich in fish. There are two currents striking the coast of Iceland. A branch of the Gulf Stream encompasses the larger part of the coast so that the country is almost surrounded by warm water. This is the reason the climate on this Arctic island is much milder than one would expect when its geographical position is taken into consideration. The other current, polar in character, comes from the north and strikes the north and east coasts of the country.

On account of these two currents with their different types of marine plant and animal life, the sea around Iceland is rich in the growth which is the basis of life for various kinds of fish such as cod, saithe, haddock, halibut, herring, and many others. Seals are numerous and millions of sea birds breed and make their homes on the seashore, on the rocks, and on the many small isles around the coast. The most important of these sea birds is the eider duck, from the nests of which the eider down is gathered.

The Icelandic fisheries are as old as the nation itself. For centuries the Icelanders used virtually only rowing boats. Later on came sailing vessels, which again, in their turn, were replaced by steam trawlers, other steamships, and motorboats. Now the fishing is run on the most scientific modern lines.

But it is not only the Icelanders who enrich themselves with the abundance of the sea. There are thousands of ships of different nationalities fishing around the coast of Iceland. During the winter nights some of the fishing banks look like moving towns, light with light, ship with ship, all fighting for the cod. But the Icelanders are, of course, best situated for these fishing grounds, and indeed they exploit them with diligence, being the fourth largest fishing nation in Europe.

Agriculture, second largest occupation of the Icelandic nation has undergone a great change although the development has been slower than in the fishing industry. Stock raising is largely pursued, the qualities of the soil being suited to it. The production of vegetables is considerable and increasing. An interesting feature of this occupation is, as has been stated earlier, the ever increasing use of natural heat from the thermal springs for growing all kinds of vegetables, fruit, and flowers. The possibilities in this respect are practically without limit.

There is a considerable amount of industry in Iceland, particularly in connection with the fisheries, and it is increasing rapidly.

Trade, both at home and with foreign countries, is extensive in proportion to the size of the population. The foreign trade is greater per person than that of any other country from which statistics are available. This is because Iceland has need of a great many products for which there are no raw materials in the country. On the other hand, the products are somewhat one-sided. The exports consist mainly of sea products, such as fresh fish, frozen, salted, and dried herring, cod-liver oil, fish meal, and agricultural products such as meat, wool, butter, cheese, hides, and skins, and eider down. Manufactured goods, groceries, and all kinds of cereals have to be imported. In Iceland there are no mines, no coal, no salt or oil. These and all kinds of machinery must therefore be imported.

COMMUNICATIONS

Communication is, as may be expected, rather difficult in Iceland. The country is mountainous and intersected by great rivers, but the population is small. Perhaps the first thing that would strike the visitor wanting to travel about in Iceland is the absence of railways. There have never been any railways in Iceland, and it is improbable that any will ever be built. Nevertheless, roads fit for motor traffic

total altogether over 3,000 miles with about 330 bridges, of which the majority have been built during the last two decades. The roads cover most of the populated districts, linking them together across highland and mountain passes. Motor roads are also beginning to reach up into the highland plateau. Motor vehicles are the chief means of transport, and have replaced the horses. But travelers wanting to reach places outside the motor roads have to resort to ponies both for riding and transport of goods. The Icelandic ponies are the most delightful animals; they are strong, sure-footed and intelligent. As a matter of fact there are a great many who prefer the ponies to the motor vehicles, and it is difficult to imagine a more pleasant way of spending a holiday than by going with a group of friends on horseback through certain parts of Iceland.

Before the outbreak of the war passenger steamers sailed regularly from Iceland to England, Denmark, Norway, and Germany. This is, of course, somewhat changed now, and two steamers have been put on the Reykjavik-New York route. Iceland hopes for improved communications with the American countries in the near future and wishes to establish a closer cultural and commercial relationship, particularly with Canada and the United States.

Telegraph lines extend over the whole country, and submarine cables, as well as a wireless telephone system, link Iceland with the rest of the world.

EDUCATION

Illiteracy is unknown in Iceland, and the general level of education is considered very high. Attendance in school is compulsory for every child up to 14 years of age. In towns the school system is not unlike what is common in the English speaking countries. But in the country, schools have not yet been built in every district, so that in some places the teachers have to use the individual homes where the children gather. A number of schools for adults have been built in the country districts. These schools are preferably erected at the side of a hot spring, and are not only heated but are also equipped with swimming baths and even steam baths.

The University is small and a number of students go abroad to various European and American countries for special studies.

The art of writing seems to be a strong inheritance because a comparatively great number of people have shown their talent in this respect. Perhaps they are encouraged by the knowledge that if they have something to say and say it well, it will be read by a whole nation, even if a small one. Nowhere are so many books and newspapers published yearly in proportion to the size of the population, and, in addition, there is imported a great number of foreign books,

for many people read one or more foreign languages. On the bookshelves in the farmsteads may often be seen a selection of world literature in the original languages.

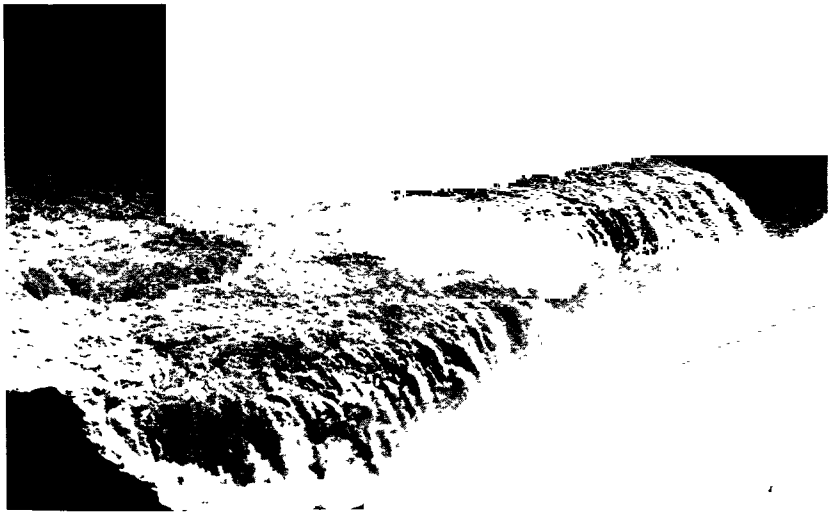
ICELAND AS A TOURIST COUNTRY

Iceland lies off the beaten track and has therefore not yet been discovered as a tourist country, except to a very limited extent. But the country has great possibilities in this respect. The number of tourists visiting Iceland has been increasing steadily in recent years and to those who love the open air and the pleasures and recreations afforded by nature, Iceland has much to offer.



1 MANY WATERFALLS ARE FORMED WHERE THE STREAMS FROM THE LAVA PLATEAU PLUNGE OVER ITS BOUNDING ESCARPMENT.

The lava banks show the typical columnar structure formed in many lava flows when they cool.



2 A WATERFALL FORMED WHERE A STREAM DROPS INTO A CRACK IN THE LAVA PLATEAU



1. SHEER CLIFFS RISE FROM THE SEA IN MANY PLACES.

The steplike benches are caused by erosion along the lines of contact of several basaltic flows.



2 ONE OF THE MANY GEYSERS AND HOT SPRINGS OF ICELAND

The out-flow of mud or mineral matter from the geyser has formed a series of stratified layers seen in the foreground.



1. COLUMNAR OR ORGAN-PIPE STRUCTURE IS COMMON IN THE BASALTIC ROCKS

The cooling of the molten rock formed the cracks which separate the lava into blocks, often roughly five-sided.



2. THE VARIOUS LAVA FLOWS HAVE FORMED STEPS ON THE PLATEAU.

The higher mountainous region is seen in the background, with a pool of water in one of the cracks in the lava in the foreground.



1. THERE ARE MANY UNUSUAL EROSIONAL FORMS IN THE VOLCANIC ROCKS OF THE ISLAND



2 A PECULIAR MUSHROOMLIKE ROCK CAUSED BY EROSION IN THE LAVAS AND MATERIAL EJECTED FROM THE VOLCANOES



1 TRAVEL, AWAY FROM THE FEW MOTOR ROADS, IS ON HORSEBACK.

Many scenic trips may be had in the vicinity of Reykjavik.



2 ICELANDIC PONIES ARE STURDY AND SURE-FOOTED.



1. SCENERY ON THE PLATEAU



2. AN ICELANDIC GIRL.



1. A WATERFALL FORMED WHERE THE STREAM PLUNGES OVER THE ESCARPMENT BORDERING THE PLATEAU.



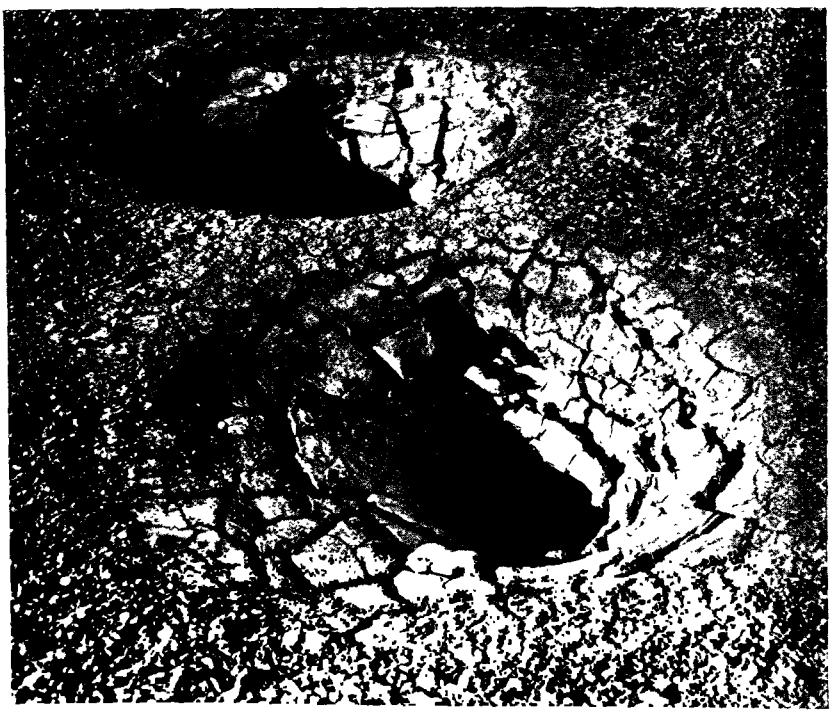
2. ONE OF THE GEYSERS IN ERUPTION.

There are many geysers and hot springs in the island.



1 CONES ARE BUILT UP AROUND VENTS WHERE LAVA OR HEATED WATERS OF THE GEYSERS ISSUE

This material is deposited in layers.



2. SINK-HOLE DEPRESSIONS ARE QUITE COMMON, EITHER AT THE VENTS OF GEYSERS WHERE THE WATER WELLS OUT OR WHERE GASES ESCAPE FROM THE HEATED INTERIOR

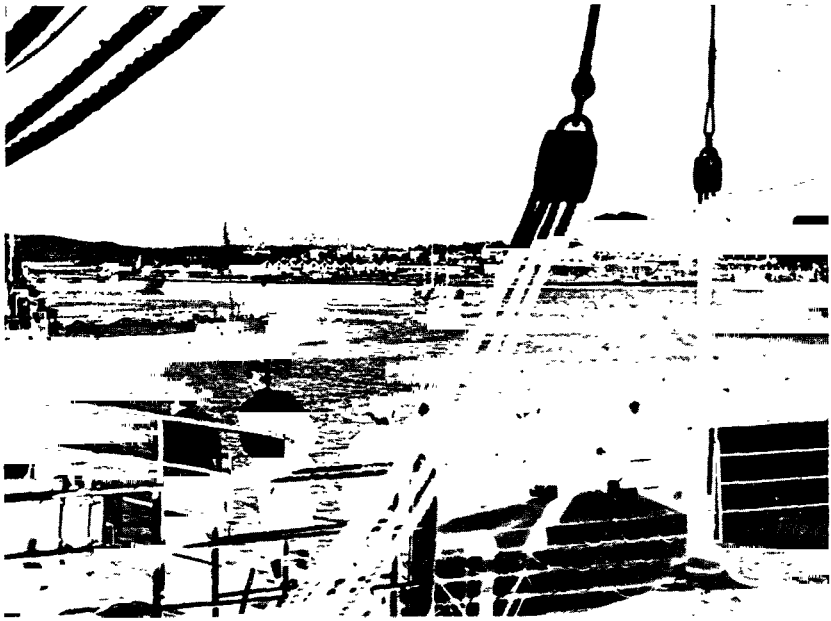


1. COASTAL SCENE IN ICELAND



2. A STREAM IN ICELAND

Note the peculiar pinnacles due to erosion in the volcanic rock.



1 CANADIAN AND BRITISH TROOPS IN ICELAND



2 CANADIAN AND BRITISH TROOPS IN ICELAND



1. CANADIAN AND BRITISH TROOPS IN ICELAND



2 CANADIAN AND BRITISH TROOPS IN ICELAND



1. A POOL IN A NARROW JOINT CRACK DUE TO THE CONTRACTION OF THE LAVA WHILE COOLING



2. ONE OF THE NUMEROUS FALLS OF THE RIVERS IN ICELAND, FORMED WHERE THE WATERS FROM THE UPLAND PLUNGE OVER THE BORDERING SCARP

These provide ample power for lighting and heating power plants.

THE GENES AND THE HOPE OF MANKIND [1]

By Bruce Bliven
Editor, The New Republic

Amazing strides have been made in recent years and even months in relation to the most fascinating of all scientific riddles—that which has to do with the origin and development of life itself. These recent achievements would have attracted far more attention than they have were it not that the world has been distracted with war and politics. Nevertheless it is quite possible that some of the work done in the past few years may be remembered for many centuries after the political and military leaders of today are gone and forgotten. In some of the great research laboratories of the United States I have recently had the privilege of seeing the extraordinary achievements in this field that science is now accomplishing.

It is hard to realize how rapidly progress has been made in relation to this subject. It is only since the year 1901 that the Mendelian law has been rediscovered after having lain forgotten for more than 35 years in a paper written by the fat Austrian monk. (It was ridiculed, when first published, by some of the leading scientists of the day.) It was more than a decade later before the extensive usefulness of the tiny banana fly in laboratory experiments was fully realized. Only in 1927 did science discover that bombarding the individual with X-rays or neutrons could produce a wide variety of mutations in the next generation, thus speeding up the evolutionary process a hundred or a thousandfold. Not until 1934 did the scientists learn that the giant chromosomes found in the salivary glands of this banana fly (*Drosophila*) could be studied under the microscope to great advantage. Finally, only within the last year or two have the scientists found out that remarkable things happen to plants when they are treated with the miraculous drug called colchicine, obtained from the roots of the bitter autumn crocus. As a result of all these things, the doors have swung open on a

[1] This is the sixth of a series of articles under the general title, "The Men Who Make the Future." They are based on interviews with numerous leading American research experts who were promised that they would not be quoted by name. Reprinted by permission from The New Republic, vol. 104, No. 15, April 14, 1941.

wonderland of new knowledge, although as yet we have only crossed the threshold.

If justice is done, there will some day be monuments all over the world to the banana fly. This tiny, light-colored insect has great advantages in the genetics laboratory. It thrives in captivity, produces one generation in only 12 days, and each female may have several hundred young; thus 2 years of the banana fly are equal to 2,000 years of mankind. Its unique giant salivary chromosomes seem almost made to order for the research of the scientists.

One of the first things to impress a layman about the new knowledge of the geneticists is the similarity of the life principle in plants and animals. In the great genetics laboratory of the Carnegie Institution at Cold Spring Harbor, Long Island, the other day I saw a chart of the genes and chromosomes of the jimsom weed, a favorite plant for colchicine experiments. Only across the hall was a similar chart for the banana fly. While there were of course differences, the similarities were even more apparent. In both cases, the living matter consists of cells. In both cases each of these cells contains a nucleus equipped with a definite number of chromosomes. In both cases these chromosomes are filled with genes. In both cases, each gene or group of them supplies a definite characteristic to the living organism. It is not too much to say that from the standpoint of science plants are only stationary animals, or that animals are perambulating plants.

In order to understand the startling new information which science has unearthed regarding all living things, with its searching implications for our own social conduct, it is necessary to describe briefly the mechanism of birth and growth, as the scientists now understand it. For the sake of simplicity, I shall use the human body as my illustration, although the process is similar throughout all organic matter.

The body consists of microscopically small cells, each containing in its nucleus 48 chromosomes that are very much smaller still. Twenty-four of these are contributed by the father and an equal number by the mother. (This rule holds good throughout the world of plants and animals, although the number of chromosomes differs with each species.) The microscopic chromosomes contain the genes and these have the clue to the very riddle of life itself. They are known to control the growth and development of so many characteristics that geneticists believe they probably dictate all growth processes. How many different genes there are in a human being no one knows; it is believed that *Drosophila* has about three thousand. Man probably possesses at least as many.

Under the microscope the giant salivary chromosomes of *Drosophila* (100 to 170 times larger than those in other tissues) look somewhat like tiny snakes with alternate transverse markings of light and dark. You must not think, however, that each dark area is one gene or even that the genes are concentrated in them. All that the scientists are willing to say is that certain genes are associated with certain dark areas and that the bands in some sense mark the limits within which certain genes are known to lie. There are of course many genes in each part of each chromosome.

There is one important exception to the rule that there are 48 chromosomes in every human cell. The male sperm and the female ovum which meet to start a new life have only 24 chromosomes each. They meet and join at the moment of fertilization and the chromosomes which appear in the cells of the offspring come from both parents. This meeting of the chromosomes and genes is not a matter of mere blind chance. Genes for the same characteristic of the individual (color of hair or eyes, pigmentation, etc.) are located always in the same chromosomes. (Any one character, such as eye color, is not, however, controlled only by genes from a single chromosome.) The genes from both father and mother jointly dictate the characteristics of the child.

As science discovered more than a hundred years ago, there are dominant and recessive characters. When they meet, we now know, the dominant will win out, as the word itself suggests. In Mendel's famous experiment, he crossed a true-breeding form of red peas with white ones. Red is dominant; white is recessive. In the next generation all the plants had red flowers, but they were carrying the white genes none the less. The self-fertilized grandchildren of these peas were 25-percent pure red and 25-percent pure white. The other 50 percent were red in color, but they, too, carried white genes, so that their descendants would not breed true to the dominant red.

Sometimes characteristics are controlled according to whether the organism possesses one gene of a certain type, or a pair of them. For example, there are two genes which, when they appear in pairs, cause a man to sing bass and a woman to sing soprano. Two other genes, in pairs, produce tenors and altos. One gene from each pair, together cause baritones and mezzo-sopranos. As Dr. Herluf Strandskov has pointed out, the children of a basso and a soprano can only sing bass or soprano; a tenor and an alto can have only children of those voices. A baritone and a mezzo-soprano is the only mating that can hope to produce a quartet!

How does a child grow from an almost invisible, microscopic fertilized egg into a 200-pound football player? He grows, and so does everything else in nature, by cell division. Did you ever put

a bubble pipe in soapsuds and blow until a mass of tiny bubbles rose above the surface of the water and almost overflowed the basin? The analogy is inaccurate, but the mental picture you will get is similar to what happens in the process of cell division. Each of the 48 chromosomes in a cell divides by splitting lengthwise into two parts, which separate, half of them going to the right, so to speak, and the other half to the left. Then the nucleus begins to narrow in the middle, into a dumbbell shape, with 48 chromosomes in each end. The bar in the middle grows shut; the two ends break off, and we have two cells each containing all the chromosomes of the original one. This process is repeated; the two cells become four, the four become eight, and so on, until their number rises into billions.

The almost unbelievable work that has recently been done is to identify the genes which create certain characteristics of the living creature. With enormous patience and countless hours of weary industry, the scientists have tracked down the characteristics associated with individual genes. (This had been worked out in theory some years before it was verified under the microscope through experiments in artificial mutation.) In the case of the jimson weed, for example, about five hundred new genes have been discovered, of which more than seventy have been located in particular chromosomes. The scientist can put his finger on the chromosome chart of the jimson weed and can say: "At this point are found the gene or genes that cause the plant to have a rough skin, or to carry tufts, or to be an albino." In the banana fly, similarly, the scientists know where in the chromosome lie the genes associated with certain definite characters such as the color of the eye, the size of the wings, bands on the abdomen, and so on. More than 500 genes in *Drosophila* have been definitely located.

A few years ago it was discovered that carefully controlled bombardment with X-rays, neutrons, or other radiation would affect the genes. Sometimes they are altered or destroyed, sometimes the arrangement of the sections of the chromosomes is changed. In a state of nature, once in many times the genes are spontaneously changed by extreme heat or cold, by old age, or for other reasons. When the organism is subjected to X-rays, the process of change is enormously speeded up. Large numbers of mutations can be detected in the short space of two generations, and the scientists are perhaps beginning to see the mechanism of evolution in operation before their very eyes.

The almost incredible fact is that the experts now know in advance in a general way what will happen when *Drosophila* is subjected to a moderately severe dose of X-ray. Perhaps half the flies will be killed. Among the survivors some will have descendants,

and among these descendants certain types of mutation will appear in definite percentages which the scientists can now predict in advance. They can tell you before the baby *Drosophilae* are born (when they are considered in sufficient quantities) about how many will have dwarfed wings, or white eyes resulting from lack of pigmentation, or other abnormalities. If mankind has ever come any nearer than this to usurping the privileges of the Deity, I do not know where.

These changes in characteristics which the scientists create in the laboratory will breed true for all time in the future unless affected by additional mutation later on. Ten thousand years from now, if these *Drosophilae* were to continue having descendants that long, their remote offspring would still have white eyes or dwarf wings, because the genes creating the normal characteristics, colored eyes, or large wings, are lacking or altered. To illustrate this with a more familiar laboratory animal: you could cut off the tails of 1,000 generations of mice and the one-thousand-and-first would have tails as long as those of the original ancestors. But destroy the chief long-tail-producing genes in a single pair of mice, and their descendants, if inbred and selected for taillessness until they are pure for this characteristic, will be tailless forever more.

The action of the genes must certainly be one of the most interesting mechanisms in the realm of nature. It is hard to believe, yet it is increasingly being proved, that almost every hereditary characteristic of the individual is to be found packed away in these microscopic particles. The genes, acting together, seem literally to plan the growing organism. Science does not yet know just how this is done, or the relation among the genes, the mysterious and miraculous glands of internal secretion, and the tissues. It is assumed that the genes control the shape that growth takes from the beginning of the new life. There are embryonic tissues, called by the geneticists "organizers," which evoke specific growth-reactions in other embryonic tissues. In the human being each of the glands of internal secretion—the pituitary, the thyroids, parathyroids, pancreas, adrenals, and gonads—secretes one or more hormones which, poured into the blood stream, keep the body functioning. Most of them, indeed, are vitally necessary for the maintenance of life itself.

It staggers the imagination to think of the genes at work through the months and years creating every organ of the complex electrochemical-physical machine for living that is the body. Either directly, or indirectly through the endocrine glands, they bring each of the organs to full usefulness at the proper time and in co-ordination with each other. Then think of the hundreds of thousands of species of animals and plants, in each of which the genes follow the

proper and unique pattern of the species, and you begin to have some idea of the wonders of this universe.

When you lift your arm or bend your finger the process is an electrochemical one. The nerve impulse from the brain sets up at the proper places in the muscles an electrically induced chemical alteration. It is possible that the genes do their work in the same way; we do not know.

Nothing is more mysterious in this whole complex story than that the genes, and the tissues and glands which they help to build up, seem to work on an elaborate and intricate time schedule. In human beings, for example, there are characteristics that do not develop until many years have passed. There appear to be "bad" genes, from the individual's point of view, which lurk unsuspected for half a century and then cause a man to become bald in just the way his father did. Others seemingly wait for decades to produce hereditary blindness or insanity. A marvelous mechanism is that operated by the gonads which brings about the characteristics of adolescence at 13 or 14, produces hair on the face of the male (in certain races) at 18 or 19, and either creates the changes of the menopause in the forties and fifties or, by ceasing to function, permits them. There are even presumably old-age genes which determine, before you are born, how long you will live—if you don't terminate your life prematurely with whiskey, a bullet, or a speeding automobile. For longevity, as everyone knows, "runs in families," and whatever runs in families, if actually inherited, is controlled by the genes. That is to say, the tissues and organs of the individual have a gene-determined life cycle that will be carried out if other factors do not intervene.

The miracle of the "time-clock genes" is clearly shown in the case of identical twins—twins which arise from a single fertilized egg which for some reason divided early in embryonic life to produce two human beings with, so far as science knows, the same genes and chromosomes. Identical twins develop the same physical characteristics, throughout life, at almost exactly the same time. This principle holds even if three, four, or five children have developed from a single egg. This is the case with the Dionne quintuplets, who have the same genes.

Let me emphasize again that it is wrong to think of a single gene as performing a specified function unaided. It is now believed that every gene influences every other, just as all the genes occur in every chromosome and there are 48 chromosomes in every cell of the body except the sperm and ovum from which the new life will be created. There are eye genes in your toe, and toe genes in your eye. Science now knows that there are certain groups of genes which are inherited

together. Often such genes appear to have no logical relation to one another, at least in the present state of our understanding. In some families of human beings, for example, a given color of hair is associated with the lack of one or more of the incisor teeth. By studying family strains it is possible to predict that a child born to certain parents, and having hair of a given color, will possess only six or seven incisors instead of eight.

This innocent-sounding fact is likely to prove of the very highest practical value to the future of the human race. Many diseases are not predominantly hereditary, but others are, and often you can inherit a predisposition. Among the hereditary ones are some that are particularly terrible in their effects, which nevertheless do not manifest themselves until middle life, after the victim has unwittingly married and had children to whom he can pass on his taint. An example of such a disease is Huntington's chorea, which does not appear until the individual is 35 or 40 years of age. Previously he may have been a fine physical and mental specimen. When Huntington's chorea strikes, he goes to pieces mentally and physically; his muscles fail; he sinks into hopeless insanity which usually terminates, after a few years, in death.

Medical science knows no way to cure this terrible malady; but the knowledge that is coming out of the laboratory gives us the hope of a means by which we could stamp it out in only a few generations. If linked genes could be discovered that are inherited together and transmitted with the disease, latent Huntington's chorea could be identified far in advance through other seemingly harmless and unrelated characteristics. No civilized person would marry and have children if he knew that such a fate overhung him and them. The time may not be far distant when, thanks to the advance of science, society can say to such an individual long before he reaches the age for fatherhood that it is forbidden to him. Other dread diseases, believed to be hereditary, for which there is now similar hope are muscular atrophy, which brings death at about the age of 20, and hereditary blindness, which may also begin in the late teens.

Opinion is divided among the experts as to whether it is possible to inherit a predisposition toward diabetes or whether its seeming to "run in families" is due to quite different causes. Whatever the scientific explanation, it is desirable that one who may develop diabetes should be forewarned and should take the necessary steps to safeguard himself by following a hygienic routine of living. Science is now prepared, by the study of family histories, to give warnings of this sort.

These new secrets of the laboratory have resulted in greatly altering our concepts of many aspects of our individual and communal life. Here are a few:

1. Geneticists are no longer interested in the old debate as to whether environment is more important than heredity. From their point of view, both are of tremendous significance. What the organism inherits is not so much characteristics as the tendency to produce these characteristics provided the environment is favorable—a profound new discovery which, if it could be grasped by political leaders in all its implications, might well make over our society. For example, there is a species of rabbit whose hair is mostly white; but if exposed long enough to low temperature, black hair grows out. Pink-flowered hydrangeas can be changed to blue by adding iron salts to the soil. Tall corn planted too close together will grow only a quarter of its normal size. Yet the offspring of these rabbits, hydrangeas, and corn, in a normal environment, will again have white fur, pink flowers, and tall stalks. When the hereditary influences are strong, those of environment are correspondingly weak, and vice versa.

These changes, however, could not have taken place unless the organisms carried the special genes that make them possible. Not all rabbits have fur that changes color; there are "Tom Thumb" breeds of corn that never grow tall no matter how widely the hills are spaced; some flowers remain the same color when fed iron salts. In other words, environment can change you, but only on a basis of what you originally possess—or lack. It is like the developing chemical in the photographer's dark room; it creates nothing, but it can bring out what is on the plate. The tragedy of life is that we so often discard the plate without ever finding the perhaps rich and beautiful picture concealed on it.

2. For practical purposes, at least, we may assume that almost nothing in our biological heritage is transmitted from one generation to the next except what is passed on in the genes. This does away at one stroke with a multitude of conceptions of the popular mind. It is nonsense to suppose, for example, that because a mother before the birth of her child receives a fright or sees a snake, the child will be "marked," any more than he will be musical or artistic if she goes to concerts and galleries.

3. There is a popular theory that whole families can be subjected to continuous decay and degeneration. This might be true under very special circumstances, if, for instance, all the good men in a community had been killed off in war, or in the case of isolated groups where inbreeding would serve to reinforce undesirable strains instead of desirable ones. The chances are, however, that when a

family seems to go rapidly downhill from generation to generation, it is only partly because of bad heredity. The rest of the story is environment—poverty, ignorance, and imitation of their elders driving down one crop of children after another.

Science nowadays looks with deep suspicion on conclusions drawn from the famous "degenerate families" such as the Jukes and the Kallikaks, with which sociologists regaled us a generation ago. No doubt there were some "morbid" genes among the members of these families; but the sociologists made a bad mistake in attributing the whole evil record to the genes alone and ignoring environmental factors. What chance would even a normal child have had, brought up in a household composed largely of drunkards, thieves, and prostitutes? His family record would be enough to turn the community against him from the start. The geneticists of today try to balance the evils transmitted by the genes against those caused by imperfect surroundings.

4. Alcoholism, as such, probably cannot be transmitted from parent to child, though an unstable neural system, predisposing to dipsomania, may be. When the son of a drunkard takes to drink, it is possible that his genes are involved; but it is also possible and even probable, that it is by imitation or in response to a bad environment in which the father's alcoholism played a part. Roughly the same is true of other human weaknesses—drug addiction, sexual promiscuity, improvidence, love of gambling, habitual lying.

5. The common belief that the mother's blood circulates through the body of the child before birth is now known to be false. The two blood streams are separated by the placenta, through which nourishment passes by osmosis, which is roughly the way that blotting paper picks up moisture. Mr. Justice Holmes in a famous decision once held that an unborn child is "a part of the mother's bowels"; but science has overruled the great Justice. The number of abnormal conditions the mother can transmit to the unborn child is much smaller than is commonly supposed. She can infect her baby with syphilis, but this is not a hereditary form, and responds to treatment. She cannot transmit gonorrhea, although she can infect the child during birth itself. Until a few years ago, thousands of children all over the world became blind at birth because of venereal infection transmitted in this way. There are a few drugs which manage to find their way through the placenta, and it is believed, for example, without much reliable evidence, that an unborn child may become a cocaine addict. Certainly the child's genes can be injured before birth by lead poisoning. But such pathological conditions, at least as between mother and child, are not hereditary and can be treated just as postnatal infections are.

As scientific knowledge improves, we learn more and more about inherited susceptibility, or predisposition, toward certain diseases, as well as resistances or even immunities. We learn that some types of illness formerly supposed to be hereditary are only partially or not at all in this category, while in other cases inherited characteristics are found to predispose an individual toward a given disease. Among those in which inheritance is a definite factor are rheumatic fevers in childhood, a few rare types of cancer, color-blindness, a number of disorders of the eye, baldness, and albinism. Certain sorts of feeble-mindedness are hereditary. The geneticists are increasingly reluctant to draw a hard and fast line between environmental and hereditary factors; yet in regard to 10 of the 12 most serious diseases, environment on the whole seems more important than heredity.

These recent scientific revelations have enormously altered our conception of eugenics. We understand now for the first time how mutations occur, through destruction or alteration of the genes. From the individual's point of view, there are good and bad genes, but the good ones enormously outnumber the bad. Since nearly all changes in the genes are destructive, and consist in taking something away, under the law of averages most mutations are undesirable. They produce an organism limited in some respects, in comparison with its parent, and therefore probably somewhat less fitted to cope with its environment.

In a state of nature, this does not matter greatly, for it is offset by natural selection—the survival of the fittest. Mutations that are disadvantageous tend to die out; good ones help the organism to survive and to transmit its desirable "symphony of genes" to the next generation. But unfortunately civilization as it has existed for the past few centuries tends to reverse this process. We are moving in the direction of keeping everyone alive, the unfit as well as the fit, and permitting nearly all of them to transmit their genes to their children. Many of the leading geneticists of the world believe that this process, continued long enough, would so reinforce the morbid genes as to bring about the degeneration of the race.

To say this is not, however, to accept the theories of those who are demanding wholesale compulsory sterilization of the unfit. The geneticists realize better than the amateur enthusiasts what an enormously difficult and complicated subject this is. They advocate sterilization in certain definite cases of proved hereditary feeble-mindedness and insanity, partly to put an end to bad genes and partly because people of low or unstable intelligence bring up their children badly. In other cases of undesirable heredity, the experts recommend voluntary abstention from parenthood.

Amazing things have been done in only a few generations to perfect plants and animals, and impatient persons often ask why the same should not be possible for mankind. It is a legitimate question and the assumed answer holds an exciting promise for the future. There is little doubt that if genetic principles could be applied to humanity, the average of our population could be brought up to the level of our best examples within a few generations. If you want a slogan, here it is: "Every man a genius by the year 2141."

The difficulty is that somebody would have to decide what are the desirable traits, after we had agreed that hereditary feeble-mindedness and insanity are undoubted handicaps. His judgments would be subjective, and that is where the trouble comes in. Who is to accept the fearful responsibility of saying what are good traits for a future society, and what are bad ones? For that matter, who is to say what the future society will be like? Will you assume a continuance of our present social organization, which seems to require large numbers of not-too-bright toilers and soldiers? Or will you envisage an ideal state of universal peace and all the heavy work done by machines?

The overwhelming obstacle is that most human beings today live in environments so unsatisfactory that we cannot tell what their genetic possibilities are. We know by scientific research that there are thousands of geniuses in this country alone who remain swamped by poverty and ignorance and never get a chance to demonstrate their abilities. Before we can live up to the promise of our genetic future, we must remove the shackles which prevent full development of our present capabilities. Otherwise, the effort at improvement is like trying to carve a statue in the dark.

The geneticists, on a basis of solid science, hold forth a glorious picture of the future of mankind. They tell us that by improving our environment and our heredity simultaneously we can in a few generations abolish nearly all human afflictions. It is sober truth to say that it lies within our power to create a race of superbeings, living in Utopia, and to do so in perhaps the length of time that has elapsed since George Washington was born. No more exciting prospect was ever offered mankind.

CARE OF CAPTIVE ANIMALS[1]

By ERNEST P. WALKER

Assistant Director, National Zoological Park

[With 12 plates]

INTRODUCTION

The purpose of this article is not to stimulate the keeping of animals in captivity, but rather to make more tolerable and, if possible, more happy the lives of those that are inevitably to be kept in captivity. Most pets are kept because the captor is fond of them. Yet in altogether too many instances the animals are not properly cared for. The result is often suffering, ill health, or death due largely to lack of knowledge on the part of the captor, who would gladly provide his pet all it needed if he but knew how.

Anyone not sufficiently fond of and interested in animals to be willing to provide the proper quarters for pets and thereafter give them proper and regular care should not attempt to keep them.

[1] Animals of many kinds have not yet been successfully kept in captivity, or if they have been so kept, the fact is not generally known. Therefore the information now available about the best ways of keeping many kinds is necessarily very incomplete. It is hoped that readers of this paper who have had experience in the keeping of animals whose needs in captivity are little known, will communicate with the author in order that the benefit of their experience may be added to his records and so be made available for others who are interested in the subject.

Acknowledgment is made to the following persons for information, assistance, and advice in the preparation of this paper: Dr. Carter H. Anthony, veterinarian, National Zoological Park; Mr. Vernon Bailey, retired, chief field naturalist, U. S. Biological Survey (now the Fish and Wildlife Service); Dr. Doris Cochran, assistant curator, Division of Herpetology, U. S. National Museum, for examination and considerable work on the reptile and amphibian sections; Mr. Malcolm Davis, principal keeper, National Zoological Park; Dr. Herbert Friedmann, curator of birds, U. S. National Museum, for examination of the bird section; Mr. John N. Hamlet, of the U. S. Fish and Wildlife Service; Mr. Roy H. Jennier, principal keeper, National Zoological Park, who has given consideration to the reptile and amphibian sections; Dr. David Johnson and Dr. Remington Kellogg, of the Division of Mammals, U. S. National Museum, for examination of the mammal section; Mr. Charles E. Kellogg, Section of Fur Resources, U. S. Fish and Wildlife Service; Dr. J. E. Shillinger, Section of Wild Animal Disease Studies of the same service; and numerous others who have at various times supplied me with information which is incorporated herein. Such a work as this is necessarily a composite of information obtained from innumerable sources, all of which cannot be specifically credited.

Mr. Gerrit S. Miller, jr., associate in biology, U. S. National Museum, has painstakingly gone over the entire manuscript to review it from both biological and editorial points of view.

When man takes wild animals into captivity and endeavors to maintain them, he sets up for himself a definite obligation to furnish them with the comforts and necessities to which they are accustomed in their native state.

The basis of the entire problem is to view the subject from the standpoint of the animal and its requirements. Experience gained in handling one animal is often of great value in the handling of related kinds, but this is not an infallible guide, as frequently related forms will have different feeding habits and requirements.

Within the scope of such a brief work as this, it is not possible to treat in detail each kind of animal; the most that can be attempted is to point out a few of the basic principles that may generally be applied, and to cite additional sources of information where further details regarding certain groups may be obtained.[2] Perhaps it will also encourage those who keep live animals to view the subject from the broadest possible standpoint, so that they may obtain new information regarding the care and requirements of their captives.

Fairly satisfactory information can frequently be obtained by correspondence or personal inquiry from well-informed sources, such as the personnel of zoos, museums, biology departments of universities and high schools, State and governmental agencies, and local naturalists.

The work of agencies for the prevention of cruelty to animals is to be commended, and well-run zoos and parks cooperate with them.

Altogether too often animals are kept as exhibits merely to attract attention to a business enterprise, and the captor has no real fondness for the animal, knowledge of its requirements, or interest in its welfare.

Unhappy, sick, or diseased animals are not pleasing pets or attractive for exhibition. Therefore, any effort on the part of the captor that will keep the animals happy, contented, and in good health, is well justified. The more one knows of the conditions under which the animal lives in the wild, the better able he will be to plan for its welfare.

It is sometimes said that certain animals cannot be kept in captivity. A better way of stating the fact would be that we do not yet know enough about the requirements of certain animals to be able to keep them successfully. Often certain people have excellent success not only in keeping but in breeding animals that others have said could

[2] The U. S. Fish and Wildlife Service, Department of the Interior, Washington, D. C., has available for distribution many publications formerly issued by the U. S. Biological Survey and the U. S. Bureau of Fisheries relating to food habits and care of many different kinds of animals, including earthworms and other forms used for bait or food of animals.

The Bureau of Animal Industry of the U. S. Department of Agriculture has issued many publications on the care of domestic stock, including chickens and ducks, that contain useful information.

not be kept in captivity. The sooner we admit that we really know very little about the lives and requirements of wild animals, the sooner we will be in a frame of mind to learn more about the subject, with correspondingly increased success in keeping them.

The observing, thoughtful person can amplify the sketchy outline given herein and find many more foods, methods, and materials useful in keeping animals. He will realize that the animals in any region eat only the plant, animal, or mineral products in their own generally restricted ranges. This will suggest many local products that are potential foods.

Adoption of the rule that "the animal is always right" will go far toward smoothing the road for both the pet and the owner. We are fond of animals because they are animals; therefore they should be allowed to live the lives of animals rather than forced to ape our lives, actions, and methods.

GENERAL CARE

In providing for animals, it is important that we give consideration to the range of temperature under which they normally live, whether their home climate is dry or humid, what kind of food they eat, and whether or not they vary their food from season to season as many animals do. We should also provide the proper type of shelter or nest, meet their requirements as to drinking water, temperature of water, and know whether or not they need to swim or to wallow in dust or mud. These are major necessities; but there are many other important details in the life of every captive animal that must be heeded if they are to be successfully kept.

Before obtaining animals,[3] persons should endeavor to ascertain the proper care for them and be prepared to render such care upon the animal's arrival. If specimens are obtained from dealers or others who have had them in captivity, it is frequently possible to obtain fairly satisfactory information as to their care. In some instances irresponsible or poorly informed dealers will give erroneous or incomplete instructions. An example of this is the advice given by circus vendors to feed anolis, which they sell under the name of chameleons, sweetened water. The animals soon die on this diet. They eat live insects, and will thrive on flies.

Obviously man cannot provide animals with exactly the same conditions they would enjoy in the wild. It is therefore of great importance that he give very careful heed to providing the substitutes

[3] Almost every nation, country, State, and Province has restrictions on the capture, possession, transportation, and importation of wild animals. Anyone who wishes to obtain animals should first familiarize himself with the restrictions of the region in which he expects to obtain the animals, and any of the restrictions that may apply to the method of transportation contemplated and within the region in which he expects to keep them.

that most closely approximate the conditions and foods they would obtain in their natural state, and that he give the animals a sufficient variety so that they may select those that are best adapted and thereby show the captor the foods and conditions preferred.

Newly acquired animals are usually much worried, fretted, and tired from a trip, and often have not had water or proper food en route. The first step in their care is, therefore, to provide them with clean, fairly roomy quarters, proper food, water for drinking and bathing, and fine sand or dust for cleaning themselves, if they use that method. Birds that require grit have usually not received it on their trip. A small amount should be given immediately. They will take too much if given a large quantity.

Let them be quiet and undisturbed so they may rest. If they are just received from the wild and are to be placed in a collection with, or in close proximity to, other animals, it is an excellent plan to exercise some quarantine precautions, such as maintaining them in quarters well isolated from the main collection, and, at the same time, treating them with insect powders and sulfur to remove external parasites, doctoring serious injuries, and taking any other safety measures that may appear necessary. Some animal custodians also follow the practice of giving some medical treatment to eliminate internal parasites, or to at least make observations of feces to determine whether or not such parasites do exist.

The shipping crates or cages in which the animals are received should be burned or cleaned and sterilized thoroughly to prevent introduction of parasites or disease.

Too often animals are displayed in the hot sun without an opportunity to get into the shade, often without water, and in other instances they are exposed to bleak winds without shelter, and without straw, leaves, or bedding to insulate themselves from cement, iron, or board floors. Such treatment is inhumane, to say the least.

Almost all animals have some sort of a home in the wild. In some instances it is a burrow deep enough so that there is almost no change in temperature in it throughout the year. In others, it is a nest made of fibrous material that is good insulation from changes in temperature. Wild animals are free to move about and choose for themselves the locations and conditions most to their liking. This is not possible for captives, so it behooves the captor to heed their needs closely, for they cannot talk our language to tell us of their wishes and sufferings.

Sunlight is essential to the welfare of many animals, but like other good things, it can be overdone. It is important that cages be placed so that the animals can choose whether to be in the sun or in the shade. Even a comparatively short period in the direct rays of the

sun is often fatal to snakes and lizards that are inhabitants of desert regions and are supposed to enjoy the sun. They regularly seek the shade during the hot portion of the day in hot weather; or they burrow in the sand or under stones to get out of the intense heat. Small den houses become unbearably hot when in the sun. Shade should be provided for such enclosures in hot weather.

Animals that particularly require sunshine frequently develop ill health and become unsightly because they do not get enough sunlight or ultraviolet rays. This can frequently be remedied by installing ultraviolet lamps at the cages so that the animals can go into the rays to such extent as they wish. Such rays can be harmful if the animal is subjected to them too much.

Sunlight is not essential or even desirable for certain animals, for, being nocturnal, many of them never see the sun, not coming out into the open until the sun is set, and going to bed before the sun rises. Others live subterranean lives entirely away from the sunlight. Presumably such creatures obtain, through their food, the materials that are manufactured by other animals in sunlight.

Developments in air conditioning, refrigeration, and special types of lighting now make it fairly easy to provide physical surroundings that closely approximate those of the climate in which animals would normally live. The big problem is to furnish suitable substitute foods. In the wild, some of the animals are what we term "specialized feeders," that is, they eat but very few kinds of food. At first thought such foods may not appear to furnish well-balanced diets. However, careful consideration will disclose the fact that their limited diet does provide a well-balanced ration for them. Feeding these animals is sometimes the most difficult of all problems, and at other times it is very simple, depending on whether or not we are able to furnish palatable substitute foods that contain the necessary constituents. Other animals take a wide variety of foods in the wild, a nibble of this and a nibble of that, obviously selecting things that are palatable to them and that contain the constituents necessary for their well-being. Careful study of the feeding habits of such animals in the wild discloses a surprising variety of food consumed. Sometimes they may eat a limited variety for a short period, but with the changes of the season, the diets may be radically changed. In some instances, such changes appear to be necessary for physical development and growth. For example, many young birds, such as finches and others, are fed insects by their parents, whereas the adults eat mainly seeds for most of the year, and insects for only a short season. In others, the changes appear to indicate a wide food tolerance that permits the animal to survive under seasonal conditions that vary greatly from one time of the year to another.

The examination of stomach contents of wild animals, which has been carried on so extensively by the United States Biological Survey [4] over a long period, has been of great value in showing what North American animals eat. The studies carried on in this manner are valuable as guides in the keeping of captive animals.

One of the most common errors in the feeding of carnivorous animals is to give them only choice red meat, on the assumption that carnivores limit themselves strictly to such food. On the contrary, in many cases when carnivorous animals make a kill, they eat the viscera of the prey or drink its blood or eat its brains before they will eat any of the red meat. Recent studies in vitamins reveal that the viscera of animals are rich in several vitamins; liver is especially rich, as are other glands of the body. Furthermore, it is probable that the digestive fluids in the stomach and intestines, which are regularly consumed by the carnivores, are really needed by these animals. The fur or feathers and skin of the victims are regularly consumed, and are obviously needed as roughage and bulk if they serve no other purpose. The bones of the victims are relished in many instances and are valuable as a source of minerals such as calcium and phosphorus; also, red bone marrow is a valuable food. Furthermore, the chewing of bones stimulates the flow of digestive fluids and strengthens the teeth and jaws.

Almost all carnivores will occasionally take plant foods to some extent, as witness the cat that will frequently chew grass, apparently taking it as a medicine or for the vitamins. Dogs do likewise. Bears, other than polars, eat mainly plant products.

Overfeeding is a frequent cause of animals becoming sluggish or excessively fat, and even dying. Care should be taken to give an animal only as much as it will clean up fairly promptly at its usual time to eat. Surplus food that remains in the cage is likely to spoil and poison the animal, and also to attract ants, flies, cockroaches, and other pests.

Nocturnal animals will not, of course, ordinarily take food that is given to them in the daytime. Their failure to take it promptly should not be construed as indicating that they are not hungry. They should be fed in the evening.

Fur farms are probably the most outstanding examples of progress in the care and keeping of wild animals in captivity, for if a fur farm is to profit, it must not only be able to keep its animals alive, but it must be able to induce them to reproduce prolifically and to be in such excellent health that their fur is of superior quality. Furthermore,

[4] On July 1, 1940, this organization was consolidated with the U. S. Bureau of Fisheries, formerly of the Department of Commerce, under the new title of U. S. Fish and Wildlife Service, and transferred to the U. S. Department of Interior.

these conditions must be produced at a minimum of cost. The many fur farms in the northern United States, in Canada and Alaska, as well as elsewhere in the world, carry on a variety of research work looking toward more successful fur farming. Veterinarians have been employed who are not merely animal doctors and surgeons, but who carry on active research in well-equipped laboratories and make many painstaking and accurate observations. Experimental fur farms of governmental agencies, such as that operated by the former Biological Survey and now carried on by the Fish and Wildlife Service at Saratoga Springs, N. Y.; their rabbit experiment station at Fontana, Calif., the Canadian fox experimental station at Summerside, Prince Edward Island, and others are at work on these problems. As a result of these studies by individuals, companies, and governmental agencies, a wonderful fund of information about the care of fur-bearing animals has been developed. Some of this is available in Government or other publications that are cited in the bibliography at the end of this paper. Naturally most of the information developed relates to the raising of foxes, minks, muskrats, rabbits, chinchillas, coypus, and a few other animals, as these are the fur bearers that are commonly raised. However, the researches and experiments have so clearly demonstrated the need of many animals for vitamins, certain foods, and certain types of treatment and care, that the basic principles can well be applied to a much wider variety of animals and to man. Research laboratories that have carried on experimental work with mice, rats, rabbits, guinea pigs, monkeys, and other animals for the purpose of developing information relative to medicines, vaccines, serums, foods and food deficiencies, and for other purposes, have likewise made outstanding contributions. These were, of course, mainly designed to advance the cause of human medicine, but their findings should be freely used by persons interested in keeping animals in captivity in the best possible condition.

Various studies have been made to determine the chemical constituents necessary for proper diet for animals. These have been carried on in various ways and much valuable information has been developed. Among the studies is the work of Dr. C. P. Richter, of the Psychobiological Laboratory, Johns Hopkins Hospital, who over a long period of years has carried on studies, principally with rats, in which he has clearly demonstrated the importance of furnishing animals with the proper amount of the various food constituents needed by them. He has carried on long feeding experiments with a great number of rats fed on diets composed entirely of solutions of starch, proteins, salts, and other ingredients. On these the animals thrived, remained active and in good health, and developed good coats. He found that by removing certain of these foods, he

could induce the evidences of ill health that frequently can be recognized in captive animals. These experiments obviously showed that some captive animals do not receive all of the food constituents needed by them. In some of his experiments, he supplied the rats with what would normally be considered good varied diets, but he also offered them the test-tube foods so that they could choose from them any ingredient that they might feel they needed. He found that they would frequently take certain test-tube food, thereby demonstrating that the supposedly good general diet they were receiving was deficient in certain constituents necessary for their welfare, and realizing this lack, they made it up by taking the relatively unpalatable test-tube material.

An example of deficiency due to an inadequate diet, and what can be accomplished by supplying a suitable diet, is the case of a woodchuck that was in the National Zoological Park. It became almost completely naked, and remained so over a period of 2 or 3 years. It was fed by Dr. Richter on his chemically complete diet, and at the end of 4 months was returned to the Zoo with as good a coat of fur as a wild marmot would ordinarily have. This animal, together with others of its kind in the National Zoological Park, had been fed with what was supposedly a varied, well-balanced diet, but obviously something was lacking which prevented its growing good fur. This is a clue which should be followed up in the hope that the specific food requirement may be found for the growing of hair. It would benefit many mammals that have a tendency to become naked in captivity, and perhaps some of the birds that suffer from feather loss. Conceivably it might even be useful to bald-headed men.

Grooming is an important activity in the lives of animals, and they will ordinarily take good care of their coats if they feel well. If they fail in this, it may be because of ill health or because they lack proper facilities. Some must have water for bathing; others, fine sand or dust; others enjoy a shower bath, and still others need to bathe in mud. Large mammals, such as elephants, rhinoceroses, and hogs, delight in daily baths of mud or water, which assist them in avoiding insect pests and parasites.

If a mammal does not shed its old fur and keep sleek and well-groomed, it is a sign that something is wrong, probably in the diet.

In addition to correcting the diet, it is well to provide bundles of brush in the cage so that the animal can comb out its fur by rubbing against it, as it would comb its fur in the wild by going through vegetation.

Human standards of cleanliness should not be the sole factor in determining cage arrangements and accessories. Fresh soil and mud

with normal bacteria is often of great value to animals, whereas human beings are likely to consider it dirty, and therefore objectionable, forgetting that the real menace to the health of their pets may lie in dangerous bacteria that multiply in food left exposed, or in food and drinking dishes not entirely clean. It is well to adopt a regular routine of sterilizing the utensils frequently, and, if possible, cleaning the cage with disinfecting solutions which are not harmful or objectionable to the animals.

The National Zoological Park is now using a disinfecting and cleaning solution made up as follows: Stock solution—5 gallons of 5 percent solution of sodium hypochlorite and 18 ounces of caustic soda (lye). Dissolve the lye in 1 to 2 gallons of water in enamelware or earthern container, then pour lye solution slowly into hypochlorite to avoid violent reaction. Stir while pouring. For use add 1 pint of stock solution to 2 gallons of water. The stock solution costs only a few cents per gallon to make and is very similar to, if not better than, a commercial product that sells for about $2 a gallon. This mixture is good for disinfecting cement floors, walls, and dishes, but is injurious to paint.

Disinfectants and deodorants should not be confused. In general, if cleaning and disinfecting is well done, there is little need for deodorants. In some cases, however, a deodorant is desirable to mask an odor which cannot be eliminated. For such, use about 4 ounces of oil of pine to a gallon of water. This is excellent and is not known to be harmful to any animal, unless it be reptiles. Many deodorants and disinfecting preparations, such as carbolic acid, phenol, creosote, and others, are harmful to animals and should not be used.

There appears to be a widespread but erroneous belief that an animal can thrive under a wide range of temperature. As a matter of fact, only a few can withstand extremes of heat and cold as great as man regularly endures. The majority have some means of avoiding extremes. Some migrate. Those that burrow obtain equitable temperatures in their dens. Others go into caves, hollow trees, masses of dead leaves, or other locations where there is good insulation from heat and cold. Further, the cavities are usually small so that the body heat of the animal is conserved.

Exercise is important in maintaining the health of most animals in captivity, though to provide suitable means for exercising is a problem for the ingenuity of the caretaker. He must, of course, know something of the type of activity that each animal normally carries on. A few suggestions are made. The larger the cage, the more likely the animal will be to obtain some exercise by moving about.

(Some caretakers maintain that certain parrots do better in small cages than in large ones.) If it is a climbing animal, trees, horizontal bars, swings, ropes, rings, and poles will all stimulate activity. Wooden or rubber balls, or other toys, even dolls, are sometimes useful, either as playthings or as companions. Wheels that will give the animal a sense of progress are particularly good. They may be of the inclined disk type, or of the ferris wheel type. (See pl. 1.) It is also probable that successful exercising devices might be developed for the small cats, or other animals of similar size, after the model of the endless-belt treadmills, such as were at one time made to utilize dog and horse power for man's purposes.

Some animals that do not thrive in captivity when kept alone do very well in groups with others of their kind. An excellent example of this is the ani; lone individuals promptly die in captivity, but groups of four to six have lived for several years in the National Zoological Park under exactly the same treatment as previously given single birds. Others thrive when a companion of another kind is with them, if one of their own kind is not available. There have been numerous odd companionships of this kind, such as the friendship between an African rhinoceros and a goat. We have in the Zoo a Javan macaque monkey that lovingly fondles its pet guinea pig, and is thus provided with an interest in life. One black-tailed marmoset in a cage by itself at the National Zoological Park was gradually failing. Presently two other marmosets of a different species were put in the cage with it. At first, it was very much afraid of them and stayed as far away as possible. After a few days, it gained a little courage and would occasionally come near the others, and finally it was participating in their play. Thus, the lethargy and so-called cage paralysis which had been coming on was averted. This example rather definitely suggests that one type of cage paralysis is the result of a wasting away of muscles due to inactivity, which can be prevented by providing animals with a good-sized cage and inducement to exercise.

When placing animals of the same kind or different kinds together, care must be taken to prevent fighting. It is a good plan to keep them in adjacent cages so they may see and smell each other for a few hours, days, or even weeks, and thus become acquainted. When they are first put together, it should be done very quietly and the animals should be allowed to make their own approach to each other. Careful watch should be kept until it is seen whether or not they will get along together. Nocturnal creatures should be watched the first night. Many animals have a very definite sense of ownership of their homes and resent intrusion by another. It is therefore

sometimes desirable to put both animals into a new cage so that neither will feel that it is the owner.

Sometimes animals will get along well together for some time, and later begin fighting. Males should usually be removed from a cage before a female is to give birth.

If captive animals are to be successful in rearing their young, it is generally essential that the female should have a nest, den, or secluded quarters of some kind during the earlier life of the little ones.

Many nocturnal animals are attractive and can become interesting pets. Their habit of sleeping during the day and being active at night is a disadvantage in some instances, and in others, an advantage. Some animals can be induced to reverse their days and nights by keeping them under a very subdued light during the daytime and at night giving them a nest box and flooding their cage with bright lights. The daylight can be reduced by filtering it through one of the celluloidlike materials sprayed with a blue-black lacquer, or blue cellophane. Special arrangements must be provided for properly cooling and ventilating the cage.

The toenails and hoofs of many animals grow rapidly in order to be adequate for their function in the wild. It is well to provide facilities for such animals to wear down their hoofs or claws. If this cannot be accomplished, it is often necessary to trim the nails or hoofs.

Many animals that would normally hibernate [5] do not if kept under unfavorable conditions. In order to hibernate they must become fat and have cool quarters so well insulated against winter weather that they will not be subject to freezing. There should be little fluctuation in temperature and the atmosphere should be definitely moist. Animals appear to have a remarkable instinct in this matter, and with a few exceptions will refuse to hibernate as long as they do not have a snug nest in a well-insulated den; but if supplied with such facilities they will promptly go to sleep. Apparently such a period of rest is required by many animals if they are to thrive.

Hibernation appears to be essential to female bears if they are to be successful in rearing their young, which are born while the mother is in hibernation. Rodents that normally hibernate rarely survive the second summer, if not allowed to sleep during the winter.

Dry leaves, grass, straw, hay, paper, cloth, and many other materials may be used for nest material and bedding. While soft tissue paper is excellent for small mammals, it sometimes sticks to the wet

[5] The ninth, tenth, and eleventh editions of the Encyclopedia Britannica contain good articles on hibernation.

newborn young. Sugarcane pulp, a byproduct, is available in bales, and is an excellent absorbent and insulating material which can be spread on cement, metal, and wooden floors to help keep the cage clean and to insulate the animal from the cold cement that is so commonly used in cage floors. This is much better than sawdust, which often contains resins that get into the fur or feathers of animals and make the animal's coat look dirty and unkempt, or sometimes causes actual staining of the coat. Most furry creatures need to have fine sand or soil in which to roll to keep their fur clean. This is particularly true of the finely furred little desert creatures that apparently cannot keep their coats in good shape unless they have very fine sand constantly available. Slightly moist soil appears to be desirable for furry creatures that regularly burrow in moist regions.

HANDLING ANIMALS

In handling practically all wild creatures, strategy, gentleness, and patience must be exercised. Most wild things will struggle violently if forcefully restrained, particularly if they are suddenly seized. Often they will dislocate wings or legs, or injure themselves. Until the animal has become well accustomed to its captor and is willing to submit to him, actual physical handling should be avoided by the use of shifting crates or cages, or the placing of a small box over the creature so that it will be quiet while the cage is being cleaned or other activities are carried on.

In handling the smaller of the small mammals in the National Zoological Park, "telescoping" cardboard nest boxes are provided. A hole is made in one end which goes through both of the walls. When the animal is in the nest, it is a simple matter to slip a piece of wire fabric in front of the hole between the two walls. This provides a very effective temporary method of restraining the animal while the cage is cleaned or in which to shift the animal to another cage. The animal feels perfectly at home in its own nest, and does not fret itself or struggle. (See pl. 2, fig. 1.)

A very effective means of transferring small and medium-sized animals from one container to another when the containers are of such type that it is difficult to place the entrances opposite each other so that the animals can go directly from one to another, is to use a large cloth bag of moderate weight, placing the entrance of the cage containing the animal in the bag, inducing the animal to go into the bag, removing the now empty cage, and then placing the bag with the animal in it in the new cage and gradually and gently working the animal out of the bag into its new quarters. Ring nets, that is, a bag or net securely fastened to a ring from 10 inches to 2 feet in diameter on the end of a pole, can often be used to excellent advantage

in capturing and transferring animals. The use of such a net eliminates the need of grasping the animal; and, when yielding materials such as cloth are used, the animals do not ordinarily hurt themselves by struggling violently.

Often a slow approach, best accompanied with gentle, slow-spoken tones, will reassure the animal, and it can then sometimes be picked up without danger of injury to itself or to its captor.

One should never grab an animal suddenly by the tail, wings, or legs. Almost invariably the animal will make a sudden start, and the tail feathers of birds may be pulled out or the skin of the tail of mammals may be stripped off the bone. If the wings or legs are clumsily grabbed, the long bones may be broken or dislocated.

When animals are to be liberated in a new cage or new enclosure, it is good practice to hang burlap or other material that appears as a definite obstacle in front of the glass or wire, so that the animal enters a place of subdued light and can see that it is enclosed. It is then less likely to dash into the glass or wires of the cage or fence. The box or shipping crate in which it was transferred to the new quarters can often be placed inside the new cage or at the entrance of the cage and left there for a time. The animal is thus permitted to choose its own opportunity to go into the new quarters, and is thus less likely to make a sudden dash and suffer injury.

When large animals, such as elephants, rhinoceroses, and other hoofed animals, are liberated from their shipping or shifting crates into their paddocks or cage rooms, it is well to place the crate so that they back out of it into the new quarters. This will often prevent a sudden charge out of the crate that might result disastrously.

To one not accustomed to working with a wide variety of animals, it is inconceivable the number of difficult situations that can arise. Animals have an abundance of time, are often energetic, can get into many predicaments, some of which may be fatal to themselves, or at other times, may be merely annoying or embarrassing to the captor. Careful thought will go far toward avoiding such unhappy incidents.

Practically all animals are much quieter when being shipped if they are screened from the view of the public. Burlap or other more or less porous material placed around or in front of the principal opening of the cage helps to make them feel secluded. Such material cannot be used if the animal is able to get its paws or hands out through the openings. In this event, small-mesh wire fabric through which the captives cannot put their hands or paws should be placed before the openings in the case or crate, and then the cloth material placed beyond it at a distance of a few inches, so that it

will be out of reach of claws or fingers. The cloth can be arranged as a curtain so that it can be raised for inspection of the interior when necessary.

FOODS

Under this heading we might include everything that can be eaten, but obviously it is impossible to list all foods that might be available or desirable for animals. Therefore, the best that can now be done is briefly to list foods that are ordinarily obtainable, or that in general must be supplied to meet the requirements of a considerable variety of animals. The saying, "What is one man's meat is another man's poison" is particularly true of animals. Some thrive on foods that would be fatal to others; therefore, if one does not know definitely just what a particular animal requires, it is important that careful heed be given to determine as nearly as possible what it probably eats, and to offer a wide variety within this range, in order that it may find among the foods offered something that will serve its purpose and not be forced to satisfy hunger by eating foods injurious to it. In general, very few animals will eat foods that are harmful to them if they are supplied with a wide variety. The instances of animal deaths from the eating of foods that are harmful are usually the result of endeavors to satisfy cravings arising from the lack of some necessary element in the food given, but sometimes they may be from actual hunger cravings.

Persons interested in maintaining animals in good condition should consider every possible food obtainable in their native haunts. It would be ideal to supply a complete array of such material, but obviously from the practical standpoint, this is impossible. It becomes necessary, therefore, to offer the animal such food as can be obtained.

In the wild, many animals that are normally supposed to feed principally on fruits or other plant life supplement their diet with insects or other animal material, and most carnivores do not strictly limit themselves to meat. While the quantity of supplementary food may be small, it appears to be of great importance, in some cases at least. Many rodents should be offered small bits of meat, mealworms, or other forms of insect life, and eggs, either fresh or boiled; also bones with dried meat on them. This material takes the place of the insects, animal carcasses and bones they would find in the wild. Carnivores should likewise be offered fruits, vegetables, and bread. The rejection of any given food on one or two occasions is not necessarily conclusive evidence that the animal will never eat it; therefore, it is a good plan to continue offering such food from time to time.

When it becomes necessary to offer animals food to which they are unaccustomed, it will frequently be found that they are hesitant about

eating it. It may appear that they are not hungry, when in reality they are, but lack confidence in the food. For this reason, new food should be left long enough for them to become accustomed to it. Such unfamiliar food will sometimes be taken only after it has been repeatedly offered to an animal. If it is possible to make a gradual change in the diet where such change becomes necessary, it is preferable gradually to reduce the food that the animals have been receiving, supplementing with the food that they are expected to consume in the future. In the course of any such change, it is important that the animal be offered as wide a variety of foods as possible, in order that it may make a selection. It is frequently found that animals eat and relish foods that experienced so-called animal authorities say they will not eat.

Protein, carbohydrate, and fat should form parts of every diet, since these are always present to some degree in every animal cell.

In general, carnivores have a higher protein requirement than herbivores and omnivores. Therefore, lean meat or some other palatable food of high protein content should constitute the major portion of their diet. Carbohydrates and fat can be utilized by these animals, but neither should replace the meat entirely because of the essential amino-acids and vitamins contained therein. Carbohydrates and fat can be used to supplement exclusively protein diets, though the former nutrient is of limited value to most carnivores. Red meat or muscle is not the sole source of protein. Tendons, connective tissue, cartilage, bone, brain, and nerves, as well as the viscera, are excellent sources of protein that are frequently wasted.

Herbivorous animals are able to digest large amounts of roughage. The latter should be of good quality in order to insure adequate protein, minerals, and vitamins. Small amounts of grain are commonly used as a supplement to the roughage.

Omnivorous animals stand somewhere between the carnivorous and herbivorous species as to requirements. Apparently they can utilize more carbohydrates than carnivores, and less roughage than herbivores.

Presumably most of the known vitamins required by man are necessary to most lower animals as well, but perhaps not in the same proportions. It is likely that furred and feathered creatures may require certain vitamins in greater proportions than mankind, at least during the seasons for growing hair and feathers.

The vitamins[6] known at this time, and a brief summary of information regarding them, are given below. Since vitamin studies have been made primarily of foods used by human beings, and evidences

[6] Most of the information regarding vitamins has been condensed from the Physicians' Vitamin Reference Book issued by the E. R. Squibb Co. and the Nutritional Charts issued by the A. J. Heinz Co.

of lack of vitamins are usually expressed as to effects on human beings or laboratory animals, the statements should be evaluated accordingly.

Vitamin A.—Known to exist in oil from cod, halibut, and certain other fishes; egg yolk, whole eggs, spinach, liver, raw carrots, cheese, fresh prunes, squash, butter, sweet potatoes, green lettuce, cream, peas, tomatoes, peaches, salmon, bananas, milk, yellow corn, and alfalfa, arranged in the order of their richness in this vitamin. In vegetables, vitamin A occurs as carotine and is known as provitamin A. Lack of the proper supply of this vitamin is evidenced by eye and skin defects, possible susceptibility to infections, and retarded growth.

This vitamin can be given to animals in the form of cod liver oil, halibut liver oil, and several well-known medicinal concentrates. The vitamin A value in cod liver oil is seriously impaired by exposing the oil to light or heat, or when the oil becomes rancid. It should be used sparingly because of injurious effects due to overdosage. Green plants eaten in sufficient quantities will ordinarily supply the animal with enough of this vitamin. Apparently all vertebrate animals require this vitamin. Pregnant and nursing females require unusual quantities.

Vitamin B_1 (thiamin hydrochloride).—Found in yeast, wheat germ, rice polishings, whole-grain cereals, peanuts, dried beans, liver, milk, nuts, malt, ham, bacon, almonds, spinach, prunes, parsnips, carrots, corn (canned), and greens, in order of the richness of their content.

Deficiencies in this vitamin in man are evidenced by lack or loss of appetite, retarded growth of young, and increased nervous excitability, pains, tremor, and muscular fatigue.

Can be supplied in cod liver oil, halibut liver oil, commercial concentrates, capsules, and drop dosages. Thought to be required by all animals, but it is known that ruminants manufacture this in their digestive tracts. Others of the B group are also manufactured by certain animals.

This compound is readily destroyed by heat and alkalines.

Vitamin B_2 (riboflavin).—Good sources are dried yeast, liver, kidney, eggs, meat, wheat germ, spinach, milk, cheese, milk whey, turnip greens, carrots, and carrot tops, kale, and cottonseed.

Deficiency in this vitamin is associated with digestive disturbances, retarded growth, reduced lactation, loss of hair and other skin troubles, eye diseases, and irritation of the gums and tongue.

Can be supplied in commercial tablets.

This compound is destroyed by strong light.

Nicotinic acid and nicotinic acid amide.—Good sources are dried or concentrated yeast, liver, lean meat, kidney, heart, buttermilk,

cabbage, spinach, wheat germ, salmon, dried whey, eggs, kale, milk, peas, potatoes, tomatoes, and turnip greens. Deficiency of this vitamin in human beings is associated with soreness of mouth, redness and itching of skin, swelling of the tongue, diarrhea, vomiting, nausea, loss in weight, indigestion, and nervous disturbances.

Can be supplied in medicines as tablets and solution for hypodermic administration (intramuscularly).

Vitamin B_6 (pyridoxin).—Good sources are dried yeast, liver, rice polishings, meat, fish, maize, whole wheat, egg yolk, wheat germ, legumes, milk.

Deficiency of this vitamin in man is associated with retarded growth, anemia, and muscular disorders. Can be supplied in capsules, or solution for intravenous injections.

Vitamin C (antiscorbutic vitamin, ascorbic acid; cevitamic acid).—Found in oranges, lemon and grapefruit juice, raw cabbage, tomatoes (fresh or canned) or tomato juice, strawberries, cranberries, fresh peas, peaches, apple juice, blueberries, asparagus, canned pineapple, lettuce, broccoli, parsley, brussels sprouts, turnip greens, spinach, and red and green peppers, in the order of their content.

Deficiency in supply of this vitamin in man is responsible for spongy, bleeding gums, loose, poratic teeth, hemorrhagic tendencies, sore and swollen joints, increased capillary fragility, edema, and scurvy. Deficiencies more frequently appear in the young than in adults. Essential for primates and guinea pigs, but known to be synthesized in the body of some animals. In addition to the foods listed above, this vitamin can be supplied in the form of cevitamic acid tablets. So little is known about vitamin C that anything given herein should be considered as suggesting watchfulness and experimentation.

Vitamin D (antirachitic factor).—Good sources are fish liver oils, butter, egg yolk, irradiated milk, and liver, arranged in the order of their richness.

This vitamin is in such small quantities in human foods that deficiencies are usually made up by giving the patient viosterol, cod-halibut liver oil, or cod liver oil. Lack of the proper supply of this vitamin in man is evidenced by improper development of bones, muscular weakness, protruding abdomen, delayed development of teeth and dental deformation. No doubt many cases of rickets, cage paralysis, and other instances of poor bone development in captive animals are the result of deficiency of this vitamin. Animals that will eat fish livers might obtain enough from this food. Some zoos now regularly use viosterol or halibut or cod liver oils to make up the deficiency.

Vitamin E (antisterility).—Good sources are wheat-germ oil, cottonseed oil, lettuce leaves, whole rice, watercress, egg yolk, meat,

milk, and grains, palm oil, peanuts, and rice oil, arranged in the order of their richness.

Evidence of lack of the vitamin is sterility, placental failure, retardation of growth, degenerative diseases of nervous system, muscular weakness, muscular dystrophy, habitual abortion. Enough of this vitamin will probably be obtained by most animals that are supplied with plenty of grain and green food. It is known to be essential for dogs and chickens, not essential for goats, sheep, or rabbits. Habitual abortions in cattle and pigs have been successfully treated with vitamin E preparations. It can be supplied in the form of medicine, as wheat-germ oil.

Vitamin F.—Certain unsaturated fatty acids, such as linoleic acid, were known at one time as vitamin F. There is little evidence to justify its use for skin abnormalities when added to the diet or when applied externally. The Bureau of Investigation of the American Medical Association holds much the same opinion. However, Weinstein and Glennar state that vitamin F may be of value in some diseases of the skin, including allergic eczema.

Vitamin K (antihemorrhagic).—Good sources are alfalfa, kale, spinach, dried carrot tops, tomatoes, chestnuts, soybean oil, and certain other vegetables, putrefied fish meal, bran, casein, alfalfa leaf meal, hog liver, hemp seed, cabbage, carrot greens, cauliflower, egg yolk, rice bran. The sources listed are not necessarily arranged in the order of their value, as little is known about the occurrence of this vitamin or the amounts necessary for animal welfare. Lack of the vitamin results in prolonged coagulation time of blood, and anemia. It can be supplied in oil, capsules, and tablets.

Pantothenic acid (filtrate factor—antidermatitis).—Good sources are dried yeast, liver, rice polishings, whole-grain cereals, lean beef, egg yolk, milk, peanuts, yeast, molasses, peas, rice bran, salmon, wheat bran, wheat germ. Lack of this vitamin is evidenced by cornified skin, dermatitis, desquamation of skin, granulation of eyelids, incrustation of mouth, retarded growth. This vitamin has been found essential for the nutrition and growth of chicks, rats, dogs.

Choline occurs in bran, egg yolk, heart, kidney, liver, pancreas, sweetbreads, tongue, fish, fruits, grains, meat, milk, root vegetables; it is most plentiful in the first eight. Evidence of the lack of this vitamin in human beings is impairment of liver and kidney functions, hemorrhagic degeneration of the kidneys, regression of thymus, enlargement of spleen. It has been found essential for normal satisfactory metabolism, lactation, growth, and structural elements in body tissues, and is known to prevent fatty livers and "perosis," or slipped tendon, in turkeys.

There is no proved commercial source.

Vitamin P.—The "permeability" vitamin (citrin, hesperidin) is a factor, other than vitamin C, in paprika and lemon peel. It is necessary for normal capillary resistance in guinea pigs. This vitamin is present in material (called hesperetin or hespendrii) flavone, a colorless crystalline substance. From it are formed numerous yellow dyestuffs, some of which (atrin) have an antiscorbutic vitamin influence.

Vitamin T.—This is a factor present in sesame oil. It is reported to produce with regularity an increase in the number of platelets in the blood of normal children. A fat, soluble substance not present in cod liver oil or olive oil—therefore not vitamin A; it has been called vitamin T.

Vitamins A and D are the ones most likely to be lacking in diets.

Many elements available in minerals are known to be essential parts of a properly balanced diet for animals. Calcium, phosphorus, sodium, magnesium, chlorine, iodine, potassium, and sulfur are required in some quantity. Smaller amounts, or mere traces, are required of copper, manganese, cobalt, zinc, iron, and fluorine.

MEATS

All animal products will be treated under this heading.

Beef, horsemeat, chickens, rats, mice, and rabbits are most commonly used. However, almost all meats will be eaten by some animals. When the flesh of larger animals such as cattle, horses, sheep, goats, or pigs is fed, efforts should be made to feed not only the red meat but also the skin, glands, such as the liver, blood, viscera, fat, bones, bone marrow, and brains.

Chickens, pigeons, mice, rats, rabbits, and other small animals should be given freshly killed, and whole, if possible.

Milk is an excellent food, especially for building bones. It is often taken by sick animals when other food is refused. Adults in good health sometimes take milk alone; and milk is a good vehicle for giving medicines to an animal. Raw eggs can frequently be mixed in it to provide very nutritious food for such animals as anteaters, carnivores that are not well, and young animals. Dried skim milk is especially useful for travelers. Evaporated milk can be used wherever raw milk is needed, and need only be diluted with water.

Chicken and other eggs are excellent foods and can be used raw or boiled, alone, or mixed with other foods.

Cheese and cottage cheese are valuable for supplying the important protein of milk.

Insects are eaten by such great numbers of animals that they should not be overlooked in providing foods for many different species.

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One of the most convenient means of maintaining a supply of insects is to raise mealworms (*Tenebrio molitor*, or *Tenebrio obscurus*). These are generally fed in the larval or worm state, which is about an inch long and ⅛ inch in diameter. Such larvae are easily raised and appear to be almost ideal food.

In the National Zoological Park, the mealworm cultures are kept in deep trays or drawers about 40 inches long, 20 inches from front to back, and 8 to 10 inches deep, with metal bottoms and a metal overhang at the top. Bran is put in the drawer to a depth of 3 or 4 inches and two layers of burlap are placed on the bran. The culture is occasionally sprinkled lightly with water to supply moisture, and pieces of potato, apple, and various green foods are put into the bran to supplement the mealworms' diet.

Because the larvae congregate between the two layers of the burlap, it is an easy matter to scoop up quantities of them after raising the top layer. It is also possible to separate them from the bran by sifting through a coarse mesh screen, allowing the bran with the dusty residue and small worms and eggs to fall back into the tray.

Small cultures can be kept in pound coffee cans, or almost any container that has ventilation and will retain the insects.

Grasshoppers, locusts, and crickets are favorite foods. Whenever they can be captured alive, they afford excellent variety in the diets of the many creatures that eat them. It is probable that grasshoppers or crickets could become staple articles of food for many animals by arranging for the capture and proper drying of them in regions where they are especially plentiful, as for example, in the grasshopper-infested regions of the western United States and of Africa. Analysis of grasshoppers shows that they are excellent food, and chickens fed on grasshoppers have made good growth.[7]

Waxworms and the adult waxmoths (*Galleria mellonella*) are excellent food for small toads, frogs, and many other creatures—particularly those that require very soft, tender insect food. They are pests of bee culturists and can sometimes be obtained from bee raisers. Cultures can be maintained in almost any sort of box or container that is tight enough to prevent the insects from escaping and that provides some ventilation, such as that given by screen wire openings. The waxworms are supplied with old bee comb on which they feed. If bee comb is not available, the insects will thrive on the following mixture: 1 part of fine corn meal, 2 parts of whole-

[7] Information on the value of grasshoppers as food for animals and methods of capture and treatment are to be found in Locusts versus agriculture (pp. 35–37), by Ignacio Villamor, published by the Agricultural Service of the Philippine Islands, Manila, P. I., 1914. This article tells of excellent success in feeding chickens with locusts; Grasshopper control in Indiana, by J. J. Davis, Circ. No. 88, Indiana Agr. Exp. Sta., Lafayette, Ind., January 1919; Grasshoppers and their control, by J. R. Parker, Farmers Bull. No. 1828, U. S. Dep. Agr., Washington, D. C.

wheat flour, 2 parts skimmed-milk powder, 1 part powdered dried yeast, and 2 parts of standard wheat middlings. This should be thoroughly mixed. When ready for use, it should be mixed with equal parts of honey and glycerine until about the consistency of wet sand.[8]

The adults, maggots, and pupae of the common housefly (*Musca domestica*) and the bluebottle or blowfly (*Calliphora* sp.) are good and convenient forms of food for a number of animals. They can be caught and raised fairly easily. One method of capturing the insects and of starting the cultures is to place in the open, where flies can get to it, a conical or pyramidal screen wire cage with a small hole in the top plugged with a cork or a piece of paper, and with a door on the side that can readily be closed. This is usually placed in a pan or tray in which is meat or fish to attract the flies, and the door of the cage is left open. The flies enter the cage to lay their eggs on the meat or fish. If one desires the adult flies at that time, he closes the door and removes the flies by inverting a wide-mouth bottle or screen wire bag over the opening in the top of the cage after the stopper or paper is removed. Now, by tapping on the sides of the cage, the flies can be induced to go upward into the jar or screen wire container in which they can then be transported to the cage containing the animal that is to be fed. The eggs are permitted to hatch into maggots. These feed on the meat or fish, and in this stage can be fed to animals, or they can be allowed to pupate and permitted to hatch into adult flies, thus maintaining the cycle. If there is a layer of sand or sawdust an inch or two in thickness on the bottom of the pan on which the meat is placed, the maggots will enter this to pupate. The pupae will hatch into adult flies in 6 to 15 days, depending on the temperature. However, by placing the pupae in a refrigerator, hatching can be delayed indefinitely. The pupae can be removed from the refrigerator from time to time in such numbers as needed, and permitted to become warm, whereupon they will hatch into flies that can be supplied to chameleons, aniles, and such other creatures as require this food. Shrews and a few other mammals, and many birds and some reptiles, will enjoy the maggots and pupae when they might not take the flies.

Cockroaches can often be readily obtained and are freely eaten by many animals. Cultures can easily be maintained.

Earthworms (*Lumbricus*) are excellent food for many animals, and cultures can be kept in rich garden soil in almost any container that will prevent the worms from escaping. Earthenware or wooden containers are preferable to tin. The soil should be slightly moist

[8] This formula was developed by Dr. Mykola H. Hydak and described by him in the Ann. Ent. Soc. Amer., vol. 79, No. 14, pp. 581–588, December 1936.

and the temperature never allowed to go over 75° Fahrenheit. Earthworms may be fed on well-decayed leaves, powdered bread crumbs, pieces of boiled potatoes, and crumbled hard-boiled eggs. The original stock can often be obtained by offering boys a small sum of money for capturing them. (The yellowish-green earthworms that are about manure piles are almost invariably refused by animals. Persons purchasing worms from boys should make certain that they are not supplied with worms from such sources.)

White worms, or enchytrae (*Enchytraeus*) are from 1 to 2 inches long and scarcely larger than threads. They are very good food for small fishes and some other small animals, and can be raised in a small container such as a granite pan 8 to 10 inches in diameter and 5 inches deep, filled to a depth of about 3½ inches with good garden soil. Moisten the soil occasionally, but do not allow it to be wet. Give the worms mashed potatoes, boiled rice, bread soaked in milk, and see that all the food is covered with soil. The temperature should be maintained between 45° and 70° Fahrenheit. Keep the top of the pan covered with a piece of slate or glass to prevent the soil from drying.

Common green frogs (*Rana*) are excellent food for otters, minks, raccoons, herons, and some snakes. They can usually be obtained from biological laboratories and supply houses, or local boys will frequently capture them for a small price. Various sizes can be obtained from those just past the tadpole stage to full-grown frogs. They are generally readily obtainable from dealers in the southern United States. The same type of material, however, is obtainable throughout most temperate and tropical regions.

Tadpoles, the tailed, early stage of frogs and toads, are excellent food for some animals and can be obtained at a small price from dealers, or can be captured in quantities with a dip net in their native haunts.

Toads are almost the exclusive diet of the hog-nosed snake. They can be obtained from dealers or captured by local boys.

Small lizards, particularly anolis, the so-called chameleon of the southeastern United States, Cuba, and Central America, are inexpensive and good food for small snakes, such as green and garter snakes. The principal food of many snakes consists of smaller snakes of their own kind or of related species.

Minnows and other small fish can usually be obtained locally by the use of dip nets or small seines, or they can be purchased from dealers.

Shrimp of various sizes, from the large kinds commonly used for human food, down to the minute forms, are excellent food for various animals. They can be used either fresh or dried. Large shrimp,

when used as food for birds that are accustomed to feeding on the very small kinds, should be crushed or ground and given in shallow water. Dried shrimp can be obtained from dealers in pet foods.

Crabs, crayfish, and other Crustacea of numerous kinds, including lobsters, are eaten by many animals. They can be fed fresh, or the dried meat can be soaked or mixed with other foods. Crab scrap, the refuse remaining from the commercial packing of crab meat, contains some meat mixed with a considerable quantity of crab shell. This material is used by some zoos with success. It is probable that the chitinous material of the shells contains valuable constituents necessary for certain animals. In particular, it may assist in keeping pink in the plumage of flamingos and roseate spoonbills. This material when fed to such birds must be finely ground and placed in water.

Fish, canned, dried, or frozen, is extensively used on fur farms and is an excellent food for foxes and other fur bearers. The livers of some fish are known to be as valuable as cod livers as a source of vitamin A.

PLANT PRODUCTS

There are probably only a few kinds of plants that do not produce material consumed by one or more animals at some time during the year, and practically every portion of the plant is used—buds, flowers, seeds, seedpods, leaves, twigs, bark, roots, and the various fleshy roots and modified underground stems that are rootlike in appearance. Such material is generally readily accessible and for the most part can be freely offered to animals. If animals generally have had a satisfactorily varied diet and do not have some particular craving due to a dietary deficiency that prevents them from using customary good judgment, they will rarely eat plant products that are not good for them.

Bananas are perhaps the most universally accepted of all foods. Many animals that have never had an opportunity to become acquainted with them eat them freely at the first opportunity. Bananas should be well ripened, preferably to the point of the skins becoming freely marked with brown or black. Most animals do not eat the skins, but there is no harm in giving the animal the whole fruit.

Oranges, prunes, apples, figs, grapes, plums, melons, apricots, and practically any fruit that is available will be eaten, fresh or dried, by some animals. Raisins are particularly convenient.

Seeds of a great variety are excellent food, and relished by many animals. The seeds most readily available in the United States are the common grains—corn (cracked), wheat, oats (whole, crushed, or rolled), rye, barley, Kaffir corn, milo maize, hemp, canary, millet, and cooked rice. Sunflower seeds are especially enjoyed, but are too rich

and fattening to be the major portion of a diet. Soybean meal, beans (cooked), and other leguminous products are excellent foods.

Wheat middlings, a byproduct of the manufacture of white flour, is largely composed of wheat germ. It is, therefore, an excellent material to put into bread and mashes, and to use otherwise.

Nuts are particularly good food for many animals. Such hard nuts as walnuts and hickory nuts, and somewhat softer nuts such as pecans, hazel nuts, or filberts, are especially valuable in providing such animals as squirrels with a means of wearing down their incisor teeth. However, if the teeth have grown to much more than normal length before the nuts are given to the animals, it may be impossible for the cutting edges to come to bear on the nuts. This will make it necessary to cut the teeth to give the animal itself a chance to keep them worn down.

Acorns, which grow throughout much of the world, are relished by a surprisingly wide variety of animals, including squirrels and other rodents, skunks, hogs, deer, bears, and many more.

Peanuts (not only the unroasted nuts, but also the roasted and the salted ones) are relished by great numbers of animals. The seeds of cherries, peaches, and almonds can be safely offered to animals.

Germinating grain and the young green grain plant are particularly rich in vitamins A and E. Many animals are very fond of this food, which can readily be supplied them by germinating the grain in pans or boxes containing a little moist earth or sand, or merely with moist cotton. A new pan of germinating or growing grain can be placed in the cage each day, or as often as is necessary.

Many waterfowl, particularly geese, normally are grass eaters. They therefore relish lawn clippings and some of the common garden weeds. A suitable substitute for fresh material of this kind can be supplied by slightly soaking bright alfalfa hay and chopping it up into short lengths. Chopped hay is especially valuable in the winter, when green food is not readily available.

Alfalfa leaf meal is now available through poultry and livestock feed houses. It is an excellent food for many animals that habitually eat hay, and for a great many that eat only a small amount of dried vegetation.

Hay of the various leguminous plants (especially alfalfa, clover, soybean, cowpea, etc.) is particularly high in protein and vitamin A and is very nutritious.

If several different kinds of hay of first-class quality can be obtained and offered to the animals, the best results will ordinarily be obtained. However, if several different kinds are not available, it is possible to do very well with hay that is well cured but which contains a mixture of weeds, grass, clover, and other legumes. The refuse left by the animals after they have picked through this should be carefully

examined to ascertain what proportion of it is not acceptable to them, and if the proportion seems unduly high, efforts should be made to obtain a different mixture.

It is very important that hay should not be moldy or musty, and that it does not contain the so-called foxtail and other grasses and grasslike plants (*Hordeum*, *Bromus*, and others) that have seeds bearing barbed awns that penetrate the mouths of the animals, causing bad sores which frequently lead to serious ulcers, and occasionally permit infectious organisms to enter through the injuries.

The custodian of animals that will eat any green food should be constantly alert to obtain the wide variety that is available throughout the year. In this category are lawn clippings, comprised mostly of grass and clovers, weeds from vacant lots, roadsides, and fields, leaves, twigs, and small branches of woody plants. Small branches are particularly desirable during the winter, when grass, clover, weeds, and leaves are not readily available. It should be borne in mind that great numbers of animals browse and make such coarse vegetation a considerable portion of their diet.

Root crops such as beets (red and sugar), sweet potatoes, and yams (raw and cooked), carrots, potatoes, parsnips, and others are valuable foods and constitute a convenient means of supplying almost all animals with fresh green food that they like.

Cabbage, lettuce, kale, spinach, celery, and other such garden products are good, and can usually be obtained.

A food mixture that meets the requirements of many animals is composed of chopped vegetables such as beets, carrots, sweet potatoes, cabbage, kale, crushed oats, and bread.

In the Tropics there are many fruits, vegetables, leaves, and stems, insects and other animals that are readily available. Such are not mentioned herein because few of them can be obtained in the Temperate Zones where most captive animals are kept.

Persons who have access to the seacoasts might well try out some of the algae (such as the so-called sea lettuce and the coarser kelps) as elements in food mixtures calling for green food. This material is found in the stomachs of many animals, and the extent to which it is taken intentionally is not known. It is known, however, that sea lettuce is used by aborigines. The seaweeds are rich in iodine, a good preventative of thyroid disturbances.

Water, fresh, clean, and pure, should with few exceptions always be accessible. Various animals in the wild have developed many different ways of satisfying their requirements for water. Some can and will drink freely from pans of water; others might die for lack of water, even when there was plenty in their pans. Certain lizards, for example, take water through their skin, and need to be

sprinkled occasionally or dipped in water. Some of the little desert mammals apparently do not know how to drink water from a container, as they are accustomed to obtaining only occasional drops of dew or rainfall from leaves and stems. Their food may be sprinkled with a little water so that they can get a few drops at a time. Animals that inhabit arid regions usually obtain most of the moisture for their systems either by manufacturing it from dry seeds they eat, or from the vegetation. In captivity, they will obtain much of their required moisture from fresh vegetation, but they should also from time to time be offered a wisp of cotton saturated with water. They may be supplied with water from a little glass sipping tube somewhat like a medicine dropper, with the point bent in U shape so that it operates as a fountain, but will give out the water only a drop at a time as the animal takes it.

It is entirely possible that the general lack of success in keeping various marine animals in captivity has been due to the failure of the captor to supply them with salt water of suitable composition. Some are accustomed to living alternately in salt and fresh water a part of each year; others spend their entire lives in either. Some appear to require salt water either for drinking or for its healing and curative properties. However, many marine animals appear to adapt themselves gradually to fresh water.

Very satisfactory artificial sea water can be made by dissolving 3½ pounds of Turks Island salt in 100 pounds of fresh water.

Minerals essential for building body tissues will ordinarily be obtained from the food if the diet is sufficiently varied and the animals' glands are functioning properly. It is, however, often desirable to supply calcium in the form of calcium phosphate, ground bone, or old dried bones on which the animals may chew.

Enough iodine can usually be supplied in iodized or rock salt if the animal will take it. If not, iodine can be given in organic form, or with the feed.

Salt requirements seem to vary widely. Salt appears to be essential to the welfare of cattle, sheep, deer, goats, horses, and rabbits, but is rejected by many animals. A safe plan is to offer it to almost all, and let them accept or refuse.

Many prepared foods can be used advantageously, such as some of the canned meats and meat mixtures. In addition, zoos and animal keepers have developed certain other foods which are listed below, together with formulas for two of them.

Bear bread.—The National Zoological Park uses bread made up in quantities of about 200 pounds at a time as follows: 100 pounds of flour, 60 pounds of bran, 2 pounds of salt, ½ pound of yeast, and 1 pound of blackstrap molasses. This is thoroughly mixed with water, allowed to rise, and is baked like other breads.

Mockingbird food.—This is made up by preparing a stock food consisting of 5 parts of zwiebach, 1 part of crissal (meat meal), ½ part of ant eggs. To this stock food add as used: hard-boiled eggs, grated carrots, ground hemp seed, and cod liver oil. The stock food can be made up in quantities and stored indefinitely.

Ensilage (silage) has been so extensively and successfully used in feeding cattle and other livestock that it might well be tried as a food for some of the wild animals kept in captivity, such as bison, antelopes, deer, sheep, goats, and others.

The prepared fish foods are the most convenient and economical diet for small aquarium fish that are kept in most homes.

"Ant eggs," which are really the dried eggs of termites, are valuable food for many insectivorous birds, and are particularly valuable when birds of paradise are moulting and growing their new plumage. It is entirely possible that these eggs would also be valuable for small insectivores.

Honey is particularly enjoyed by bears.

SOURCES OF FOOD

To obtain suitable foods for various animals kept in captivity will frequently tax the resourcefulness of the caretaker. It should be borne in mind, however, that pet stores and animal dealers generally carry some of the unusual types of material required. In addition to the markets and stores that sell the usual vegetables, meats, fish, seeds, and fruits, bakeries can supply stale bread which is still palatable and excellent animal food. Meat-packing plants and abbatoirs can furnish animal offal, some of which is particularly valuable. In poultry markets, the viscera and heads of chickens, turkeys, and other fowl can be obtained. Fish livers can often be obtained at fish markets, wharves, and canneries.

Biological supply houses are also usually able to furnish articles that are not on the ordinary market, such as frogs, tadpoles, toads, snakes, and other wild material. Another means of obtaining food is to solicit the help of local boys, who are almost invariably interested and willing, for a small consideration, to obtain such material as insects, worms, frogs, toads, salamanders, crabs, crayfish, and plants. Valuable help can also be obtained from fishermen, hunters, and trappers, who may be willing to supplement their incomes or to tell one where and how to capture material.

CAGES AND ENCLOSURES

Animals are so varied in their needs that many different types of cages, enclosures, shipping crates, and other devices are needed for safekeeping and displaying them under conditions which will maintain them in good health. In general, all devices for restraining

animals must be made adequate as to safety, must provide ample space for the animals to move about and obtain exercise, and should be so constructed as to be easily cleaned. Large enclosures that are fenced for retaining such animals as horses, zebras, deer, antelope, kangaroos, etc., may be of almost any convenient size, depending on the area available. They may be large pastures in which people may walk or drive. If the general public is to view the animals from outside the enclosure, it is preferable that the enclosures have a depth from front to back of from 150 to 200 feet; a greater depth is likely to permit the animals to get so far away that the public does not obtain a good view of them. The front, where the public is to pass, may be of any convenient length, but should not be less than 50 feet for the larger animals. The restraining barriers for enclosures of this type can be wire fences, palisades, rock walls, or moats, or combinations of any or all of these. The moat treatment requires greater ground area, but is particularly effective in that there is no obstruction of the view. If the moat is properly constructed, the animals can be entirely secure.

The conventional cage varies from small bird cages made of wire or partially of glass, to large cages adequate for gorillas and other powerful or dangerous animals. The size and, to some extent, the type of material to be used will largely be determined by the kind of animal to be enclosed. In general, no cage should be smaller than five times the length of the animal, although probably the majority of animals are kept in smaller enclosures. Since maximum visibility of the animal is particularly desirable, the cage should be of strong material of small dimensions so that it will cause the minimum obstruction to the visitor's view, at the same time furnishing adequate security. Glass can be used for many cages.

In constructing cages side by side, there should either be a solid partition between them so that the animals cannot get their toes, fingers, arms, or legs through into the adjoining cage where they might be bitten or otherwise injured, or, if mesh partitions are used, these should be double and far enough apart so that the animals cannot reach into the adjoining cage.

Aquaria and tanks can vary in almost infinite degree, from the cans or pans in which small boys frequently and sometimes successfully keep fishes, toads, frogs, and turtles, up to elaborate aquariums and large tanks.

Restraining the animal by means of a collar about the neck or, in cases of some monkeys, a belt immediately in front of the hips, or a strap on the legs of birds is frequently practiced. Before leaving an animal entirely unwatched in the early stages of making it secure in this manner, it is well to make certain the animal does not become entangled in the chain or leash attached to the collar or belt. Some

animals regularly become entangled, with the result that they strain or injure themselves. Others appear to learn quickly how to avoid such troubles.

When animals are so restrained, it is particularly important that the chain be short enough so that it cannot become entangled with such objects as pegs in the ground, limbs in trees, crossarms on posts, or other obstructions.

If careful attention is given to choosing species that will not harm each other, and sufficient space and suitable conditions are provided, very attractive and interesting groups can be maintained. For example, in a large cage or outdoor enclosure with pools or other natural features, several different species of birds (see pl. 4, fig. 1), reptiles, and mammals can be exhibited if properly selected. Large cages with many individuals of a single species afford considerable activity; and if belligerent individuals are eliminated, such groups frequently do well and multiply, if provided with the proper facilities for nesting or rearing young.

Heed should always be given to placing cages, aquaria, or chained animals where conditions can be comfortable regardless of the weather and without too much dependence on the thoughtfulness of caretakers.

Modern steel alloys, particularly the so-called stainless steel of the 18 and 8 group, are exceptionally good material for cage construction, as they are very strong and do not corrode under contact with excretions and secretions of the animals. The dull finishes are preferable, as they are less conspicuous to the eye. Electric welding is particularly desirable in the construction of such cages, as it provides a maximum of strength with a minimum bulk of material. The aluminum alloys should be avoided, as all that have come to my attention when used for making cages have been subject to very rapid corrosion from the excretions and secretions of the animals. When in contact with steel, this action is still further accelerated.

In regard to all cage and paddock construction there should constantly be borne in mind the fact that there must be no sharp projections about the cage on which animals can hurt themselves. Ends of wires should be carefully bent or otherwise guarded to prevent animals from injuring themselves or leaving tufts of hair or fur on them. If there is to be more than one animal in an enclosure, it is well to avoid having any of the walls come together at angles less than 90°. Angles of about 135° are to be preferred as they will provide no narrow corners into which one animal can drive another and harm it. The same idea should be borne in mind in constructing shelter houses for the larger hoofed animals.

Practically every enclosure should have some kind of a shelter or nest box. Houses may be built in the corner of the yards for large

animals, or dens just outside the cage with an opening into it, or for small creatures, nest boxes placed in the cage.

It is desirable to provide the most natural type of surroundings possible. Well-drained earth, sand, or gravel surfaces for animals that are not vigorous diggers should be provided. Burrowing animals can often be provided with soil in enclosures having cement or brick walls, and bottoms several feet below the ground level. These are good for such animals as badgers, skunks, prairie dogs, and many others.

Cement floors are extensively used, but in many respects are very bad for animals. It is to be hoped that more resilient, less absorbent, less heat-conductive material will be found and generally adopted.

It is preferable not to ship male deer when they have large antlers, but if this cannot be avoided, due heed should be given to providing ample protection so that the animal cannot get into situations in which it will harm itself, or from which it cannot extricate itself. Never ship deer while the antlers are in the velvet if it can possibly be avoided.

Shipping containers should be carefully constructed to make certain that there are no sharp or rough places inside on which the animals can injure themselves. Furthermore, there must be no point at which the animal can get its hands or feet out through cracks, or it may break its legs or strike at other animals or transportation employees. The bottoms of crates should be so constructed that they drain quickly, and bedding should be provided on the floor. Crates for hoofed animals should be provided with shallow cleats or roughened sufficiently to provide good footing.

Mangers or other containers for food and water should be so placed that they can be refilled by transportation crews with a minimum of trouble, and it is important that they be so placed that they can readily be removed, cleaned, and put back into place after refilling. Full instructions should be placed on the outside of the crate as to the care of the animal—that is, as to range of temperature at which it should be maintained, whether it is to be kept away from steam pipes or must be kept warm, not to leave in the hot sun, the kinds of food, quantities, and times it should be fed and watered and, if the trip is a long one, full instructions relative to cleaning the cage. Cages intended for long trips should be provided with so-called foot boards or long, narrow, clean-out doors at the bottom which will permit keeping the cage clean without allowing the animal to escape. Such doors, however, must be so attached that they can readily be unfastened and fastened by the caretakers, and so secured that the animal cannot get its legs out through them.

In place of foot boards, a false movable bottom like a very shallow drawer can be used for animals that are not heavy or do not stand on the floor all the time.

In general, only a single animal should be placed in a shipping crate or compartment in a crate. Often animals that would get along nicely together in large quarters under normal quiet surroundings will fight and injure each other when placed in close quarters and subjected to the irritations and excitement of transportation. Many entirely unnecessary losses occur by crowding animals together under such conditions. If two animals are accustomed to being together and they are especially fond of each other, it is sometimes safe to send them in this manner. A safer way, however, of permitting them to have the benefit of companionship and at the same time not take risks on their fighting, is to place them in the same crate with a partition between. The partition should be of such small mesh that the animals cannot get their toes, tails, or ears into the adjoining compartment where they might be injured.

The size of the crate for shipping animals is subject to great variation, depending upon the kind of animal and the length of the trip. In all cases, however, the crate should be large enough so that the animal can take its normal position without being crowded. Under no circumstances should the crate be so small that the animal must be shoved into it and compelled to hold itself in a strained position. It should be unnecessary to mention such a subject, but occasionally it is found that animals have actually been shipped under such conditions. The larger animals, such as horses, cattle, and large antelope, are most often shipped in crates that are slightly more than the length of the animals, and sufficiently high so that the animal does not injure its head against the top, and but little wider than the body so that the animal cannot turn around in it. However, if the animal is to go on a long trip, it is desirable that the crate be large enough so that it can move about freely. In some instances, animals in narrow crates have thrown themselves over backwards, landed on their back and been unable to get up.

Most of the small mammals, reptiles, amphibians, and some birds regularly take shelter if they have the opportunity to do so. It is therefore an excellent plan to provide in the shipping crate a small box with appropriate nest material so that the animal can go into it and feel secure and sheltered. This greatly facilitates cleaning the cage, for the animal will soon learn to stay in the box while the cage is being cleaned, or if it does not do this, it is an easy matter to close the entrance to the box while such work is being done. Pains should be taken to make certain that animals can keep themselves clean and dry. This is sometimes accomplished by providing a shelf slightly above the floor, on which the animal can repose much of the time, or by furnishing a wire-mesh bottom to the cage. Occasionally such animals as beavers and other semiaquatic creatures are shipped with

water, but without opportunity to dry themselves. This often results fatally.

Exterior handles should be provided on shipping crates so that transportation crews will have no difficulty handling the containers. Express charges are by weight, so shipping containers should be as light as possible consistent with strength and adequate size.

MEDICAL AND SURGICAL CARE

In spite of the extensive studies that have been made of human ailments by the medical and allied professions, much remains to be learned about these ailments, and how they should be treated. It should be borne in mind that great numbers of people, with vast resources at their command, have participated in these studies, and their subjects—other human beings—have been able to cooperate with the research workers by telling of their ailments and otherwise facilitating the study. With wild animals the problem is radically different. We must assume that they are subject to more or less the same general types of ailments that their human relatives suffer; but, naturally, every one of the thousands of different kinds of animals has its own particular reactions to its own particular ailments.

Very little has been done in the study of animal diseases, except as to fur-bearing and domesticated species. Because the subjects cannot cooperate by describing their symptoms we must assume, for all practical purposes, that we know very little about the details of their ailments, and the precise medical and surgical treatment that should be given. This emphasizes the importance of preventive measures to keep captive animals fit, rather than depending on medical or surgical treatment after ill health has set in. Proper feeding and the prevention of undue exposure to contagion or injury will go far in helping us toward the desired goal.

Evidences of ill health should be constantly watched for, and any unusual condition should be carefully observed. Diarrhea, constipation, failure to eat, excessive thirst, dullness of the eyes, unusual lethargy, and convulsions are indications that something is wrong. Other symptoms, such as purulent discharges from the eyes and nose, rapid or labored breathing, ragged or rough-appearing pelage and plumage should also be looked for. A trained observer can use these various symptoms as guides to the probable nature of the disease.

A few treatments are now fairly well known, and can usually be applied safely by competent veterinarians with fair chances of success. Medicines should ordinarily be given only by veterinarians. Sometimes, however, physicians will give advice when a veterinarian is not available.

Struggling with an animal to control it while giving it medical or surgical treatment often does more harm than can be offset by the treatment. If treatment is essential, care and strategy should be used. Animals can be rendered sluggish by giving certain drugs in their drinking water. Small creatures can be anesthetized in closed containers. Medicine can often be given in food without arousing the animal's suspicions.

The size of the dose of medicine should in general be proportionate to the size and weight of the animal; that is, a small animal should be given a small dose, and a large animal a large dose.

So-called cage paralysis probably has numerous causes. Inactivity has been mentioned. Rickets is another frequent cause. Proper food, sufficient sunlight, and in some cases supplementary feeding of ricket-preventing medicines and foods will go far toward obviating this condition.

Occasionally some mammals lose their hair gradually or fairly rapidly and do not grow new coats. A corresponding condition sometimes exists in birds. The cause of this loss of hair and feathers is not definitely known, but in some instances it is caused by deficiency in diets, though just what dietary measures can be used to prevent it is, in the majority of cases, still uncertain.

Some birds, particularly parrots, develop the habit of plucking their own feathers and eating them, or plucking the feathers of their cage mates. Apparently this indicates a dietary deficiency, which has been remedied in some cases by giving salt, fat, bones, and meat. On other occasions such methods have been without beneficial effect.

The incisor teeth of rodents in captivity are often found to be so long the animal cannot eat. In such cases, it is necessary to cut the overgrown teeth to a proper length. These teeth grow continuously throughout the life of the animal, and the animal will usually keep them worn down if it has plenty of wood, nuts, or other hard materials to gnaw. If one of these chiseling teeth is broken, the opposing tooth must usually be cut at frequent intervals.

If animals are kept on cement floors without earth or other material over them, careful watch should be kept for corns on the soles of the feet, or actual wearing away of the skin and flesh to the bone. (See pl. 8, fig. 2.)

Toenails must sometimes be trimmed.

It is often desirable to render flying birds flightless so that they can be kept on lawns or in large enclosures without wire covers. Heretofore this has generally been accomplished by amputating the terminal joint of one of the wings. This is a more or less brutal and disfiguring method. Another method—cutting one of the flight tendons—which causes little pain and does not disfigure the bird, was

developed and described by Dr. Charles R. Shroeder and Karl R. Koch.[9] Persons attempting to use this method should be certain that they sever the proper tendon, for otherwise the birds are not rendered flightless.

In some regions flies (*Stomoxys calcitrans*) persistently bite the ears of dogs, wolves, coyotes, and foxes. If the animals cannot get into a dark den away from the insects, it is well to saturate a cloth with a mixture of 10 parts kerosene, 1 part pine creosote, 1 part turpentine, and 1 part oil of murbane, and hang it at such a location that the animal will rub its ears on it as it walks about the cage, or spray the animal lightly and the cage heavily with this solution, or some other that will keep the flies away. Tar put on the edges of the ears has a beneficial effect in preventing fly injury.

Some animal keepers have placed quinine in the drinking water of ailing animals even though there was no specific diagnosis to show that quinine was desirable. However, there is no evidence that quinine is useful in the treatment of animal ailments in general. On the contrary, pure palatable drinking water is known to be of great value. Therefore, the indiscriminate dosing with quinine is mentioned only to discourage the practice.

Apparently it is essential that the females of some animals eat the placenta or afterbirth in order to start their milk flow. Many animals do this.

SPECIFIC INSTRUCTIONS FOR THE CARE OF ANIMALS

The greatly abridged information that follows relative to the care of mammals, birds, reptiles, and amphibians, is presented to help inexperienced persons in caring for the animals that may fall into their hands. The order of arrangement in each of the groups follows a more or less widely accepted scheme of scientific classification, each group starting with the lowest or least specialized, and going to the highest or most specialized.

In the case of animals that are more or less regularly kept in captivity or that are known to have been successfully kept, the instructions are specific and very abridged. In the case of those that are not known to have been kept in captivity, or only rarely or with poor results, information will be given about their known habits in the wild in the hope that this may furnish clues to successful handling.

MONOTREMES: EGG LAYERS (MONOTREMATA)

ECHIDNAS or SPINY ANTEATERS (Echidnidae). Primitive burrowing, egg-laying mammals, inhabitants of Australia and Tasmania. Feed mainly on

[9] Journ. Amer. Vet. Med. Assoc., vol. 97, No. 761, pp. 169–170, August 1940.

insects. Rarely kept in captivity, but one has lived for 38 years in the Philadelphia Zoo on a diet of one raw egg and one pint of milk daily, with one teaspoonful limewater added to the milk. The yolk of the egg is unbroken when placed in a shallow dish separate from the milk.

PLATYPUS or DUCKBILL (Ornithorhynchidae). A primitive egg-laying mammal of Australia, now rare in the wild, and almost never kept in captivity. Inhabits streams, and burrows in the banks. Feeds on small mollusks and probably on water insects. One captured young was kept 4 years on a diet of tadpoles, worms, grubs, beetle larvae, duck eggs beaten up and placed in a vessel of boiling water until the mixture boiled up like milk, then fed in water. The platypus lacks teeth, so apparently needs fine grit with its food.

MARSUPIALS: MOSTLY POUCHED MAMMALS (MARSUPIALIA)

OPOSSUMS, MOUSE-OPOSSUMS and WATER OPOSSUMS (Didelphiidae). Almost omnivorous. Should be fed on meat, insects, milk, bread, eggs, green corn, fruit, vegetables, green leaves, and honey. The smaller kinds are so mouse-like in appearance that they are frequently mistaken for rodents, but they have sharp-pointed noses and lack gnawing teeth.

DASYURES (Dasyuridae). Almost omnivorous animals of varied habits. Should be offered meat, insects, eggs, bread, bananas and other fruit, some green vegetation, seeds, grain.

TASMANIAN WOLF (Thylacinidae). Feed meat, supplemented with bread, fruit, vegetables, milk, and eggs.

BANDED ANTEATER (Myrmecobiidae), An insect eater not known to have been successfully kept. Try meat, eggs, milk, bread, fruit, and soft or soaked seeds.

BANDICOOTS (Peramelidae). The feeding habits of these marsupials are varied and little known, some of the animals being very rare. Offer grass, clover, and other green vegetation, hay, seeds, meats, insects, bread, and eggs.

MARSUPIAL MOLE (Notoryctidae). Mainly insectivorous, but probably also eats bulbs and fleshy roots and stems. Offer insects, meat, bread, vegetables, green vegetation, seeds soaked in water.

CAENOLESTES (Caenolestidae). Extremely rare and little-known inhabitants of Andes. Not known to have been kept in captivity. Try same diet as for opossums.

PHALANGERS (Phalangeridae). This group contains some specialized feeders, but most of its members eat fruit, honey, and vegetation. The koala, or Australian bear, eats almost nothing but eucalyptus leaves. The smaller kinds are known to eat petals of flowers, flower nectar, and insects. If feeding habits are not definitely known, offer wide variety of green vegetation, fruits, bread, insects, and honey.

KANGAROOS and WALLABIES (Macropodidae). Give them grass, clover, weeds, leaves and twigs of trees, vegetables, grain, hay, bread.

WOMBATS (Phascolomyidae). Burrowing, herbaceous feeders. Offer vegetables, grain, grass, clover, weeds, and hay.

EDENTATES (Edentata), HAIRY ANTEATERS (Myrmecophagidae). In the wild, these animals feed almost exclusively on ants or termites, perhaps supplemented with other small insects. In captivity, individuals sometimes do fairly well on a diet of mealworms and raw eggs and milk stirred up together. Will not survive chilling.

SLOTHS (Bradypodidae and Choloepodidae). Tropical inhabitants of trees. Leaves, buds, twigs, and fruit furnish almost all of their food. The three-toed

sloth (*Bradypus*) has not generally been successfully kept in captivity, but the two-toed sloth (*Cholocpus*) thrives on a diet of lettuce, bananas, leaves, and twigs. They like to go into the water to bathe, but are easily killed by chilling. Sloths hang beneath limbs and cannot stand upright. Therefore, they should be provided with substantial limbs or vines on which to climb.

ARMADILLOS (Dasypodidae, Euphractidae, Chlamyphoridae, and Tolypeutidae). Powerful diggers that feed almost exclusively on insects and perhaps to some degree on carrion. Some of them have been very successfully kept when fed mealworms, ground meat, eggs, and milk. Some are so nearly toothless as to be unable to tear pieces of meat. Armadillos probably thrive best when permitted access to the ground, but the walls and bottom of the cage in which they are to burrow must be of well-constructed cement. They cannot survive cold weather.

PANGOLINS (Manidae). Large-scaled inhabitants of Africa and southern Asia. Powerful burrowers. Feed mainly on insects, termites, and ants. Have not generally been successfully kept in captivity, although some have done fairly well when fed on mealworms, ground meat, milk, and eggs. One very young animal thrived in the hands of a sailor for more than a month on a diet of green beans that had been chewed by the sailor. It also received some canned milk.

CLOVEN-HOOFED ANIMALS (ARTIODACTYLA)

CATTLE, SHEEP, GOATS, OLD WORLD ANTELOPES (Bovidae). Feed grass, clover, weeds, leaves and twigs of trees, chopped vegetables, grain, and hay. Keep rock salt constantly before them.

AMERICAN PRONGHORN ANTELOPE (Antilocapridae). Feed grass, clover, alfalfa, weeds, grain, hay, chopped vegetables, and rock salt. Do not generally thrive in captivity, especially in the eastern United States. Possibly large enclosures and a wide variety of food might give better results in keeping them.

GIRAFFE and OKAPI (Giraffidae). Browsing animals, but giraffe are successfully kept on a diet mainly of hay, chopped vegetables, grain, green vegetation, and rock salt. The few okapies that have been taken into captivity have been fed a wide variety of green vegetation, hay, grain, and vegetables. Probably require salt.

DEER, ELK, MOOSE (Cervidae). Feed grass, clover, weeds, leaves and twigs of trees and shrubs, hay, grain, chopped vegetables, and rock salt. Moose (*Alces*) forage extensively in swamps and stream bottoms, consuming lily roots and leaves, grasses, leaves, and twigs. Have not generally done well in captivity. Caribou and reindeer (*Rangifer*) do not require the so-called reindeer mosses (lichens, *Cladonia*), although they of necessity feed on them extensively on their northern ranges.

MOUSE DEER, WATER DEER OR CHEVROTAIN (Tragulidae). Feed grass, clover, weeds, leaves and twigs of trees and shrubs, hay, grain, chopped vegetables, and rock salt. Keep warm.

CAMELS and LLAMAS (Camelidae). Feed green vegetation, chopped vegetables, hay, grain, and rock salt.

HOGS and PIGS (Suidae). Feed chopped vegetables, grain, grass, weeds, leaves and twigs of trees, acorns and other soft nuts, meat, and bread. Some must be kept warm.

PECCARIES, (Tayassuidae). Same care as hogs.

HIPPOPOTAMI and PIGMY HIPPOPOTAMI (Hippopotamidae). Feed grass, clover, weeds, hay, and a mixture of chopped vegetables and grain.

ODD-TOED HOOFED ANIMALS (PERISSODACTYLA)

HORSES, ZEBRAS, and ASSES (Equidae). Feed grass, clover, weeds, leaves and twigs of trees, chopped vegetables with grain, hay, and rock salt.

TAPIRS (Tapiridae). Feed wide assortment of green vegetation, chopped vegetables with grain, hay, and salt. Tropical animals; require warmth, but some individuals have thrived outdoors in northern climates. Give them a good-sized pool of warm water.

RHINOCEROSES (Rhinocerotidae). Grazers and browsers in the wild. Feed wide assortment of green vegetation, hay, chopped vegetables, grain, and rock salt. They enjoy mud wallow or shower. Avoid chilling.

ELEPHANTS (PROBOSCIDEA)

ELEPHANTS (Elephantidae). Feed wide variety of green vegetation, hay, bread, vegetables, grain, and salt. Will survive moderate cold.

HYRACES (HYRACOIDEA)

HYRACES or OLD WORLD CONIES (Procaviidae). Small creatures supposedly related to the elephants. One group lives in trees, the others live mainly around cliffs and rocks. Feed grass, clover, leaves and twigs of trees, hay, chopped vegetables, grain.

SIRENIANS (SIRENIA)

SIRENIANS or SEA COWS, MANATEE (Trichechidae) and DUGONG (Dugongidae). Marine inhabitants of tropical seas, feed on marine and brackish-water vegetation. Offer lettuce, kale, and other fairly soft green foods if marine and brackish-water vegetation is not available. Must have tank of warm water. Will not survive chilling. Have not generally been successfully kept.

WHALES, PORPOISES, AND DOLPHINS (CETACEA)

WHALES, PORPOISES, and DOLPHINS. Mostly large marine mammals, some of which are specialized feeders. Only a few of the smaller porpoises are known to have been kept in captivity for short times. Occasionally porpoises, dolphins, and belugas or white whales are kept in tanks and fed mainly on fish.

FLESH EATERS (CARNIVORA)

LIONS, TIGERS, LEOPARDS, JAGUARS, PUMAS, and SMALLER CATS (Felidae). Feed meat, viscera of animals, skin, hair and feathers, milk. The smaller ones will thrive best on whole chickens, pigeons, rabbits, guinea pigs, mice, rats, and milk. Some of the cats will take bananas and other fruits, also bread and vegetables. The fossa of Madagascar is so rare that it is seldom seen in captivity. Little is known of its habits or the best care for it. Try same treatment as for medium-sized cats.

CIVETS, GENETS, BINTURONGS, and their relatives (Viverridae). Feed mice, rats, birds, meat, including skin, hair, feathers, and glands, liberally supplemented with fruit, vegetables, bread, milk, and eggs. Certain animals of this group normally feed mainly on fruits and other vegetation, and apparently all of

them use considerable fruit. They are all tropical and subtropical animals that require protection against cold.

MONGOOSES and their relatives (Herpestidae). Feed meat with skin, hair, feathers, and glands; small birds, mice and rats are particularly good. Some of this family are especially fond of snakes, and others like crustaceans, such as crayfish, shrimp, and crabs. Also offer fruit. Tropical and subtropical animals that require protection against cold. The importation of mongooses into the United States is prohibited by law.

HYENAS (Hyaenidae). Feed the large brown, spotted, and striped hyenas meat with skin, hair, feathers, and plenty of bones. The aardwolf has weak jaws and small teeth, and is primarily an insect eater. Feed it cooked ground meat, insects, eggs, and try mice and small birds.

DOGS, WOLVES, COYOTES, and FOXES (Canidae). Feed meat with skin, hair, feathers, bones, and viscera; also fruits, vegetables, bread, milk, and eggs. Much has been written about the care of dogs and foxes. (See bibliography.)

CACOMISTLE, RINGTAIL or BASSARISCUS (Bassariscidae). Feed meat, mice, small birds, insects, and some fruit and green vegetation.

RACCOONS, COATIMUNDIES, KINKAJOUS (Procyonidae). The kinkajous will thrive best on fruit, boiled sweet potatoes, eggs, and some meat, including mice and small birds. Raccoons and coatimundies will eat meat, fish, frogs, occasionally snakes and lizards, fruit, bread, and some vegetable materials, such as corn in the milk, acorns, and boiled sweet potatoes. Kinkajous and coatimundies are tropical animals and should not be subjected to chilling.

PANDAS and LESSER PANDAS (Ailuridae). Feed the lesser pandas meat, eggs, bread and milk, fruit, honey, bamboo, grass, clover, and other green vegetation. The large panda is generally supposed to feed mainly on bamboo, but is apparently almost omnivorous, and should be offered a wide variety of vegetation and fruit, milk, and some meat.

BADGERS, MARTEN, SABLE, SUN BADGERS, SKUNKS, OTTERS, and their relatives (Mustelidae). These carnivores eat a wide variety of food. Feed whole mice, rats, birds, meat with hair, feathers, viscera, and bones, insects, fruit, some green food, soft nuts, bread, milk. Many of these animals consume quantities of insects and crustaceans; also some fish, frogs, and snakes. Otters have been generally supposed to feed mainly on fish and crustaceans, but the most succcessful otter keeper has found that they thrive best with a wide variety, such as crayfish, frogs, snakes, worms, insects, and a limited amount of fish. Sea otters have not been kept in captivity. They feed mainly on sea urchins (Echinodermata), mollusks (Mollusca), and small amounts of crab, mussel, fish, as well as other marine animals and some marine plants.

BEARS (Ursidae). Omnivorous. Feed meat with skin, hair, feathers, viscera, and bones, insects, fish, liberally supplemented with fruits, grass, clover, and other vegetation, including acorns and other soft nuts, bread, milk. Fond of honey and other sweets, which may be given in moderation. In temperate and cold regions they should be permitted to hibernate quietly in a secure den sufficiently insulated and provided with bedding so that there is no danger of their being subjected to freezing temperature. Captive bears in general do not raise their young (which are born while the mother is in hibernation) unless they can have such conditions.

SEALS, SEA LIONS, WALRUSES (PINNIPEDIA)

SEA LIONS, SEA BEARS, EARED SEALS, AND FUR SEALS (Otariidae). Feed almost exclusively on fish and squid. Sea lions fed on fish are readily kept in capitivity. Fur seals have not generally thrived. Should have large pool.

WALRUSES (Odobenidae). Walruses mainly eat clams and other mollusks—possibly other sluggish marine animals and perhaps some plants. Have not generally been successfully kept in captivity, although young animals have survived on milk and fish for a few months.

EARLESS or HAIR SEALS (Phocidae). The crab-eating seal of the Antarctic feeds mainly on small crustaceans, but has survived for a few months in captivity when fed small pieces of fish. The remaining seals are primarily fish feeders, and do well on a purely fish diet, although some will occasionally take birds and warm-blooded animals. Should have pool.

RODENTS OR GNAWERS (RODENTIA)

TREE SQUIRRELS, "FLYING" SQUIRRELS, CHIPMUNKS, SPERMOPHILES, MARMOTS, and PRAIRIE DOGS (Sciuridae). Feed a wide variety of vegetable material, such as nuts, acorns, tree seeds, bark, twigs, leaves, fruit, green grass, clover, weeds, roots such as beets, carrots, sweet potatoes, and dried materials such as hay, grains, seeds. Some meat and bones with or without meat should be constantly available for them to gnaw to wear down their teeth. Insects are relished by many. Young squirrels and others of this group have been successfully raised with cats as foster mothers. Numerous requests are received as to how to raise young squirrels. No known method is well tested; but the following formula for human babies has been used with excellent success in some instances: 3 parts whole milk (unpasteurized), 1 part prune juice, 1 part water, a very small amount of calcium gluconate or other invert sugar. A little beaten egg is added about every other day; and it has been suggested that the addition of a very small amount of the vitamin B group and a drop of viosterol might improve the formula. Very young squirrels should be fed about every 2 hours with an eye dropper or a doll nursing nipple. When they are ready to take some solid food, give uncooked rolled oats, seeds of maple and elm and other soft seeds, also lettuce, grapes and other fruit, carrots, bread, and, later, nuts.

Some squirrels are tropical and will not stand chilling. Others are hardy. Always provide nest boxes with plenty of nesting material; likewise trees and branches with rough bark, and exercise wheels.

POCKET GOPHERS (Geomyidae). Feed green or dried grass, clover, weeds, vegetables such as carrots, sweet potatoes, beets, seeds, bone, and wood on which to gnaw. These rodents are burrowers that rarely come to the surface of the ground. Unless they have dirt in which to dig, they generally do not thrive.

KANGAROO RATS, POCKET MICE, and SPINY MICE (Heteromyidae). Feed assorted seeds, small amounts of vegetables, green and dried vegetation, and bread. All of them should have fine, clean sand constantly before them with which to keep their fur in good condition. They enjoy running exercise wheels. Several members of this group become delightful pets.

BEAVERS (Castoridae). Feed twigs and limbs of a wide variety of trees and shrubs, but preferably of aspen or cottonwood; also grass, clover, weeds, bread, and vegetables. Should have a tank of water, but must have a well-drained place on which to dry their fur and also a nest den. They must have plenty of wood on which to gnaw to keep their incisors worn down. Even then, the teeth of captive beavers sometimes require cutting.

DORMICE (Muscardinidae). Feed same food as listed for squirrels and mice.

MOUSELIKE CREATURES (Cricetidae). This family contains many attractive and interesting little rodents whose combined ranges embrace almost the entire world. The habits of many cricetines are not well known, but some of these animals can be successfully kept when fed with a considerable variety

of seeds, vegetables, green vegetation, fruit, and meat, and supplied with bones, wood, cardboard, and other material for keeping their teeth worn down. Nest boxes should be well supplied with nest material. Animals from the Tropics should not be subjected to chilling.

MALABAR SPINY MOUSE (Platacanthomyidae). Little-known inhabitants of southern India and Cochin China, and not known to the author to have been kept in captivity. Try same food as for Cricetidae.

BAMBOO RATS (Rhizomyidae). Feed vegetables, green leaves and stems, hay, seeds, fruit. Must have wood or bones to gnaw. May consume some meat. Inhabitants of the Tropics; should not be subjected to chilling.

MOLE RATS (Spalacidae). Same care as for bamboo rats.

MICE and RATS (Muridae). This very large family contains, in addition to the well-known house mice and house rats, many attractive and interesting animals that inhabit most of the Old World. The habits of some kinds are little known, but many have been successfully kept by the same care as outlined for the mouselike creatures (Cricetidae). Those from the Tropics should not be subjected to chilling.

AFRICAN DORMICE (Graphiuridae). Not known to the author to have been kept in captivity. Try same materials suggested for Cricetidae—the mouselike rodents.

MOUNTAIN BEAVER, SEWELLEL (Aplodontiidae). Almost all of the numerous efforts to keep it in captivity have resulted in prompt failure. In the wild the animal inhabits a very humid region and feeds on a wide variety of vegetation, burrowing into hillsides for shelter, but spending much time on the surface of the ground or in low vegetation.

LARGE AFRICAN "FLYING" SQUIRREL (Anomaluridae). Not known to the writer to have been kept in captivity. Try foods similar to those of tree squirrels.

DWARF or LONG-TAILED AFRICAN "FLYING" SQUIRREL (Idiuridae). Not known to the writer to have been kept in captivity. Try foods similar to those of tree squirrels and mouselike creatures.

JUMPING MICE (Zapodidae). Feed seeds, green vegetables, grass, clover; provide with plenty of nest material. Must be given facilities for hibernating in winter.

JERBOAS and their relatives (Dipodidae). Feed assorted seeds, bread, and small quantities of green vegetation such as lettuce, and vegetables. Should have fine, clean, dry sand constantly available to keep fur in good condition.

AFRICAN JUMPING MICE or GUNDI (Ctenodactylidae). Not known to the author to have been kept in captivity. Try same treatment as that recommended for the Cricetidae—mouselike and ratlike creatures.

AFRICAN JUMPING HARE (Pedetidae). Feed vegetables, lettuce, grass, clover, and other greenery; also grains and hay.

CAPE MOLE RATS, or NAKED SAND RATS (Bathyergidae). Feed vegetables, lettuce, grass, clover and weeds, seeds, and plenty of live roots; also give them bones and woody plant stems on which to wear down their teeth. These are burrowing rodents of the Tropics, some of them practically naked. They should have soil in which to burrow and a uniformly warm temperature.

OLD WORLD PORCUPINES (Hystricidae). Feed vegetables, greenery, some hay, and keep well supplied with wood and bones so they can keep their teeth worn down. Animals of the Tropics; should be fairly warm. Unlike the American porcupines, they are not tree climbers.

AMERICAN PORCUPINES (Erethizontidae). Feed vegetables, grain, and a wide variety of twigs and leaves, and, for the North American porcupines, there

should be a generous inclusion of spruce, fir, and pine twigs. Should have heavy trees and limbs to climb.

SPINY RATS (Echimyidae). Feed the same as mouselike creatures (Cricetidae).

AFRICAN ROCK RATS (Petromyidae). Not known to the author to have been kept in captivity. Try feeding like Cricetidae.

NUTRIA or COYPU (Myocastoridae). Feed grain, vegetables, green vegetation, hay, including an abundant supply of twigs and limbs so that they may keep their teeth worn down. They need a pool in which to swim and dry land on which to sun themselves; also a nest box. Now being extensively raised in captivity for their fur.

HUTIAS or TREE RATS (Capromyidae). Feed grain, vegetables, green material including twigs and branches so that they may keep their teeth worn down. Should have heavy, rough-barked trees and branches on which to climb.

AFRICAN POUCHED RATS (Thryonomyidae). Feed similarly to Muridae and Cricetidae.

BRANICKS RAT (Dinomyidae). Very rare, but can probably be kept in captivity by being fed chopped vegetables, grain, green vegetation. Possibly will eat some dried green material such as alfalfa hay.

PACAS (Cuniculidae). Feed vegetables, green material (including twigs and limbs), hay, grain, and meat. Supply bones for gnawing.

AGOUTIS (Dasyproctidae). Feed vegetables, green material, dried vegetation. Supply wood and bones for keeping their teeth worn down.

VISCACHAS and CHINCHILLAS (Chinchillidae). Feed grains, vegetables, green vegetation. Supply wood and bones for gnawing.

SOUTH AMERICAN CHINCHILLA RATS (Abrocomyidae). Try feeding same as Cricetidae.

GUINEA PIGS and CAVIES (Caviidae). Feed grain, vegetables, greenery, hay, meat. Supply bones for gnawing.

CAPYBARA (Hydrochoeridae). Feed grain, vegetables, green material, and meat. Supply wood and bones for gnawing. Should have pool of warm water in which to bathe. A tropical animal and should not be subjected to chilling. The largest of living rodents.

HARES, RABBITS, AND PIKAS (LAGOMORPHA)

HARES and RABBITS (Leporidae). Feed vegetables, green vegetation, hay, grain, and salt. Certain animals of this group are now extensively raised, while other wild ones are almost never successfully kept in captivity. Scrupulous cleanliness, and the keeping of the animals in coarse-mesh wire-bottom cages or in large pens, might facilitate the successful keeping of some of the more delicate kinds. (See bibliography.)

PIKAS (Ochotonidae). Animals of the higher mountains of the Northern Hemisphere. They have not been much kept in captivity. Try same methods as outlined for rabbits and hares.

AARD-VARK (TUBULIDENTATA)

AARD-VARK (Orycteropidae). Feed insects (such as mealworms), milk, and eggs.

INSECTIVORES (INSECTIVORA)

Many of the insectivores are very small, nervous creatures that have not been successfully kept in captivity. Some of them must eat almost continuously or

they will starve to death. Therefore, food and water should be left before them almost constantly.

TREE SHREWS (Tupaiidae). Feed insects, such as mealworms, waxmoths and larvae, ground meat, eggs; also try ripe bananas, and other fruits. Tropical animals that will not survive chilling.

ELEPHANT SHREWS (Macroscelididae). Feed mealworms and other insects; also meat. Try eggs, ripe bananas, and earthworms. Tropical animals. Must not be chilled.

GOLDEN MOLES (Chrysochloridae). Feed insects, earthworms, meat, eggs; also try green material, vegetables, and fruit.

HEDGEHOGS (Erinaceidae). Feed mealworms, ground meat, earthworms, milk, eggs; may take some fruit and green food.

MOLES (Talpidae). Feed mealworms, earthworms, ground meat, eggs, milk; make available small quantities of seeds that have been soaked in water, and small quantities of green vegetation and vegetables. Moles are burrowing animals, and apparently soon fret themselves to death if they cannot burrow or at least keep themselves well sheltered from light. They are most likely to thrive if the soil is slightly moist, but not wet.

SHREWS, WATER SHREWS, SUN SHREWS (Soricidae). Feed mealworms, earthworms, ground meat, milk, rolled oats, eggs, nut meats; offer thoroughly ripened bananas, tender green vegetation, vegetables, seeds soaked in water. Shrews are burrowers, mostly inhabiting moist locations. They should be given water in which to bathe or swim, and moist moss in which to seek shelter, but should have a dry nest.

SOLENODONS (Solenodontidae). Feed insects, mealworms, earthworms, ground meat, eggs, milk. Burrowing animals that probably thrive best if provided with soil in which they can burrow. Should not be subjected to chilling.

TENREC (Tenrecidae). Not known to have been kept long in captivity. Try feeding same as shrews.

COLUGO (GALEOPITHECIA)

COLUGO or FLYING LEMUR (Galeopithecidae). Not known to the author to have been successfully kept in captivity. Presumably omnivorous. Offer insects, ground meat, eggs, milk, bread, thoroughly ripened bananas, and other fruits; also good assortment of green vegetation. Inhabitants of the Old World Tropics. Chilling must be avoided.

BATS AND FLYING FOXES OR FRUIT BATS (CHIROPTERA)

FRUIT BATS or FLYING FOXES (Pteropidae). Feed bananas, oranges, and a wide variety of fruits. Perhaps will take some meat and eggs. The importation of fruit bats into the United States is prohibited by law.

INSECTIVOROUS BATS (Rhinopomidae, Emballonuridae, Noctilionidae, Nycteridae, Megadermidae, Rhinolophidae, Hipposideridae, Phyllostomidae, Natalidae, Furipteridae, Thyropteridae, Myzopodidae, Verpertilionidae, Mystacopidae, Molossidae). Mainly small insectivorous bats, most of which occur in the Tropics, although some of them range extensively through the Temperate Zones and even into the sub-Arctic region. Very few have been kept in captivity; but the success that has attended the keeping of some kinds indicates that others might be kept by similar methods. The author kept a big brown bat (*Eptesicus*) in his home. The animal was shut in a cage during the daytime, but each evening it was given an opportunity to fly about the rooms.

Others of the same genus have been kept in the National Zoological Park for more than 2 years. The author's bat and those kept in the National Zoological Park have been fed almost exclusively on mealworms. Other people have had fair success when they fed various insects or meat. Cheese, cream, and dog food have likewise been found satisfactory. It would be a good plan to offer well-ripened bananas and other soft fruit to any captive tropical bat as some of them probably consume such material in the wild, in addition to their principal diet of insects. Some of the insectivorous bats are known to be carnivorous, killing and eating other bats and small birds. Some also eat flower petals. Water should be available at all times, as they drink frequently and copiously. A slightly moist atmosphere appears to be favorable to all bats, and many are inhabitants of the exceedingly humid Tropics. If the bat is to remain active, the temperature should not fall much below 70°, as bats either hibernate or migrate to avoid cold weather. If they are to hibernate, they should be maintained in a temperature of between 40° and 50° with very high humidity.

VAMPIRE and FALSE VAMPIRE BATS (Desmodontidae). Can be successfully kept when fed defibrinated blood, or fresh uncoagulated blood. Keep in uniformly warm temperature.

FISH-EATING BATS (Noctilionidae). Bats of this family catch small fish and perhaps insects from the surface of the water. Try feeding tiny fish or small pieces of fish, insects, meat. They may also eat some fruits.

LEMURS, MONKEYS, APES (PRIMATES)

Most monkeys do not survive chilling, but a few can withstand moderate winter weather. Some individuals of species from the Tropics become hardy and spend much time outdoors in winter if they are given the opportunity.

AYE AYE (Daubentoniidae). An inhabitant of Madagascar, uncommon in the wild and exceedingly rare in captivity. Apparently feeds mainly on insects, but probably also eats fruit. Natives say it eats bamboo. Try feeding insects, ground meat, eggs, fruit, leaves.

TARSIUS (Tarsiidae). Feeds mainly on insects, and probably also eats fruit. Try feeding insects, meat (raw and cooked), eggs, fruit, some soft green leaves such as lettuce.

LORIS, SLOW LORIS, POTTO, GALAGOS, and LEMURS (Nycticebidae). Apparently omnivorous in the wild. Feed insects, meat both raw and cooked, eggs, fruit, green vegetation, seeds, milk, bread.

MARMOSETS (Callitrichidae), HOWLING MONKEYS (Alouattidae), NIGHT MONKEYS (Aotidae), CACAJOUS, OUKARIS, SQUIRREL MONKEYS, SPIDER MONKEYS, WOOLLY MONKEYS, CAPUCHINS (Cebidae), BABOONS, MACAQUES, VERVETS, GRIVETS, PATAS, LANGURS, and COLOBUS (Cercopithecidae). Almost omnivorous in the wild. Feed the widest possible variety of fruits, vegetables, lettuce, cabbage, kale, sweet potatoes and other root vegetables, meat (cooked and raw), eggs, bread, milk, leaves, seeds and nuts that are not too hard for them to open. The langurs and colobus monkeys are primarily leaf eaters and will consume a higher proportion of leaves of a wide variety than most of the other monkeys. It is well to vary the diet from day to day.

GIBBONS (Hylobatidae), ORANGS, CHIMPANZEES, and GORILLAS (Pongiidae). Feed similarly to the preceding families. Young animals should be given practically the same care as babies and young children.

BIRDS [10]

OSTRICHES (STRUTHIONIFORMES, STRUTHIONIDAE)

RHEAS (RHEIFORMES, RHEIDAE)

CASSOWARIES AND EMUS (CASUARIIFORMES; CASUARIIDAE, DROMICEIIDAE)

Birds that are members of the four groups listed above can be kept under essentially uniform treatment. They eat vegetables, sweet potatoes, carrots, white potatoes, apples, and some form of green food such as kale, cabbage, or alfalfa hay, ground or cut into pieces about the size of a man's thumb. To such mixture may be added "bear bread" cut in 1-inch cubes; also small stones and oyster shell as grit. Supply water for drinking. Emus enjoy bathing and should have a pool of sufficient size. Ostriches are fond of dust baths.

KIWIS (APTERYGIFORMES, APTERYGIDAE)

Nocturnal birds. Feed in the evening by burying mealworms or small strips of meat (the size of an earthworm) in the soil on the floor of the cage. The bird probes for its food. This method is used in the Zoo in Wellington, New Zealand.

TINAMOUS (TINAMIFORMES, TINAMIDAE)

Feed grain, ground bread, green food, mealworms, and a pinch of ground meat.

PENGUINS (SPHENISCIFORMES, SPHENISCIDAE)

Specialized feeders; some eat small Crustacea (Euthosia), which form a red thin scum on the Antarctic Sea (Ross Sea) known as krill to the whalers; this feed is impossible to supply or imitate in captivity. The large and medium-sized penguins do fairly well when fed fish cut into strips about 3 inches long and ¼-inch wide, with the vertebrae removed. It is desirable to soak the fish occasionally in cod liver oil. The jackass penguin will eat some oyster shell. The Antarctic penguins are accustomed to very low temperature and all of them appear to be particularly susceptible to respiratory infections. It is therefore desirable to provide them with artificially cooled rooms (pl. 2, fig. 2), the air of which is frequently changed by the introduction of air that has been filtered to free it of dust and micro-organisms, and from which most of the moisture has been removed. This type of care should be provided continuously from the time the birds are brought to temperate regions. The throat infection to which penguins are subject is caused by mold of a type that grows freely on hay and straw. Such bedding should be kept away from them until they are in their permanent quarters and even then should be introduced only when needed as nesting material and only after it has been subjected to treatment that will kill the spores of the plant. The black-footed or jackass penguins do fairly well in captivity in the Temperate Zone without elaborate facilities for their care. They appear to thrive best in temperatures ranging from about 55° to 60°. The Galápagos penguins do not require artificial cooling, as they are accustomed to live on desert islands at the Equator.

[10] Cod liver oil should be supplied to practically all birds that are kept indoors.

LOONS (GAVIIFORMES, GAVIIDAE); GREBES (COLYMBIFORMES, COLYMBIDAE)

In the wild these birds eat mainly fish and small aquatic animals. Although common in the wild, they are so rare in collections as to indicate that the proper procedure for successfully keeping them has not been hit upon. It is possible that if they were supplied with large tanks or pools in which they could feed on small live fish, and perhaps were given some finely chopped or ground green material, such as lettuce or kale, they might be kept successfully. Most of the loons that are brought into zoos have been captured on the ground where they have failed in making migrations. Therefore, it is possible that these captives are injured or in poor health. If healthy birds were captured, or young taken, they might be kept successfully.

ALBATROSSES, SHEARWATERS, PETRELS, AND THEIR ALLIES (PROCELLARIIFORMES)

These are oceanic birds that fly a great deal and obtain minute crustaceans and perhaps other small life from the surface of the ocean. The albatrosses are, to some extent, scavengers and will devour refuse from ships' galleys after the manner of gulls. They are almost never kept in captivity. If one would attempt to keep these birds in captivity, he should provide them with a pool of salt water in which to swim, and offer them meat, shrimp, crab meat, crayfish, or other Crustacea, all finely ground, fed to them on the water. They might be induced also to take other foods, as is suggested by the observations that the albatross will feed on ships' refuse. It should be remembered, however, that the mouths of all the birds of this group are small, and food for them must be in very small pieces.

TROPIC-BIRDS, PELICANS, GANNETS, FRIGATE-BIRDS (PELECANIFORMES)

TROPIC-BIRDS (Phaethontidae). Feed small fish, or strips of fish, dipped in cod liver oil. Provide them with a pool of water. Do not allow to be chilled.

PELICANS (Pelecanidae). Thrive on a wide variety of fish, either small ones weighing about a pound, or pieces of large fish cut up. They take the fish freely from the hands or when tossed to them, and will also take them from the water. The average pelican will eat from 3 to 4 pounds of fish a day, but care must be taken to prevent them from overeating and 1 day's fast a week is desirable to keep them in good condition. Pelicans should have a good-sized pond for swimming and bathing, and some ground area. They will nest and rear young. Do not subject to freezing.

BOOBIES and GANNETS (Sulidae), CORMORANTS (Phalacrocoracidae), SNAKE-BIRDS (Anhingidae). Feed small fish whole thrown into the water, or pieces of larger fish cut into strips roughly an inch in cross section and 3 to 4 inches long. Provide with pools or tanks with a little land to rest upon.

FRIGATE-BIRDS (Fregatidae). Powerful fliers of the high seas, rarely kept in captivity. Most likely to thrive if kept in a large flight cage containing a pool of water. Can be fed on the wing by tossing to them fish which they will catch in midair. If such a cage cannot be provided, it is sometimes necessary to hand-feed them, or they may take the fish from the surface of the water.

HERONS, STORKS AND THEIR ALLIES (CICONIIFORMES)

HERONS, BITTERNS (Ardeidae). Feed fish, frogs, meat, mice, some ground bread and green food. These are wading birds that obtain much of

their food in the shallow water of streams and ponds. If pinioned, they can be kept in fenced enclosures with pools, or they may be kept in cages.

WHALE-HEADED STORKS (Balaenicipitidae). Habits and food similar to the above.

HAMMERHEADS (Scopidae), STORKS and JABIRUS (Ciconiidae), IBISES and SPOONBILLS (Threskiornithidae). Should be given a wide variety of food, including fish, meat, ground bread, finely chopped green vegetation and vegetables. These birds are waders, but they will take their food from solid surfaces. They can be kept pinioned in fenced enclosures, or in cages.

FLAMINGOES (Phoenicopteridae). Specialized feeders that obtain their food while wading in shallow water. They subsist mainly on small Crustacea and other minute animals found in swampy regions. Can be successfully kept in captivity on a mixture of bran, rice, wheat, bread crumbs, crab meat, crab scrap or ground shrimp, and bone meal. These materials should be in small particles mixed together and fed in shallow water so that the birds can obtain it by straining it out as they pump the water through their beaks.

SCREAMERS, DUCKS, GEESE, SWANS (ANSERIFORMES)

SCREAMERS (Anhimidae). Feed mixture of grains, bread crumbs, chopped green vegetation and vegetables, with a small amount of ground meat. Can be kept in large fenced enclosures if pinioned, or in cages. Should have ponds in which to wade and swim.

DUCKS, GEESE, and SWANS (Anatidae). Require same food as the screamers, but take less meat. A flock consisting mainly of geese and swans should be fed proportionately more green food than is required by the ducks. Should have good-sized ponds or pools. Mergansers are fish-eating ducks that thrive best if they are given a plentiful supply of small live fish to catch. Will sometimes survive on a diet of fish cut in small strips and meat finely ground or cut. The sea ducks, such as the eiders, scooters, and harlequins, consume a considerable variety of small animal life and also some vegetable material. Not generally kept in captivity; but with care might survive on fish, meat, crab scraps, or shrimp, clams, bread crumbs, some soaked grain and green material, all ground together. Should have large, deep pools in which to dive.

VULTURES, HAWKS, FALCONS (FALCONIFORMES)

All the birds of this order will eat either meat or fish or both. The larger kinds can be fed meat in large pieces or on large bones. The smaller kinds thrive best on whole small animals, such as rabbits, pigeons, mice, or sparrows, and the larger ones should have such food at frequent intervals, in order to obtain the fur, feathers, and viscera, which appear to be essential to their welfare. Bald eagles are particularly fond of fish. Vultures thrive on fresh meat, and there is no reason to give them spoiled meat. Ospreys feed almost exclusively on fish.

MEGAPODES, CURASSOWS, PHEASANTS, HOATZINS, CHICKENS, TURKEYS, GROUSE, PEACOCKS, QUAILS, GUINEA-FOWL (GALLIFORMES)

Feed a mixture of grains, green feed, ground meat, and fruits, especially bananas. Mealworms and other insects and mice are relished. Supply crushed shell, coarse sand, or fine gravel for grit. Dust baths should be provided. Size

of enclosures can range from cages to yards with moderate-height fences, provided the birds are pinioned. Ample ground area for exercise is desirable; also plenty of sunshine. Some of these birds are hardy inhabitants of rigorous climates; others are natives of the Tropics and cannot survive cold weather. There is an extensive literature regarding the raising of many of these birds. See bibliography for a few citations.

CRANES, RAILS, AND ALLIES (GRUIFORMES)

BUSTARD-QUAILS (Turnicidae), COLLARED HEMIPODES (Pedionomidae). Feed same as cranes, rails, coots, and gallinules.

ROATELOS and MONIAS (Mesoenatidae). Feed same as cranes, rails, coots, and gallinules.

CRANES (Gruidae). Feed a mixture of grain, chopped or ground leafy material and vegetables, bread crumbs and meat. They also enjoy mice, lizards, and insects, and some take a small amount of fish.

LIMPKINS (Aramidae). Same as above.

TRUMPETERS (Psophiidae). Feed same as poultry. They easily become tame enough to eat out of one's hand.

RAILS, COOTS, GALLINULES (Rallidae). Feed finely cut or ground mixture of meat and fish with a small amount of grain, plenty of green feed, and bread crumbs. They are not primarily grain feeders nor fish eaters, so there must be a plentiful supply of green food and all of the material should be finely divided, as the mouths of the birds are small. Some swim and wade extensively, so should have ponds. Others prefer to perch and spend little time on the ground or water.

SUN-GREBES (Heliornithidae). Give same food as for Gruiformes, but it should be ground or chopped more finely.

KAGUS (Rynochetidae), SUN BITTERNS (Eurypygidae). Feed fish and a mixture of meat, green vegetation, bread crumbs, mice, mealworms, and small pieces of bone.

CARIAMAS (Cariamidae). Feed grain, meat, bonemeal. Mice and young or small birds, such as sparrows, are essential for the fur and feathers.

BUSTARDS (Otididae). Feed meat and a mixture of green feed, bread, and grain. The birds of this order can be kept in cages, but thrive best in large outdoor runs.

SHORE BIRDS, GULLS, AND AUKS (CHARADRIIFORMES)

JACANAS (Jacanidae). Tropical marsh birds that probably feed mainly on insects, insect larva, small fish, and green material. No information is available to the author as to the keeping of these birds in captivity. Try mealworms, and finely ground meat, green vegetation, and shrimp.

PAINTED SNIPE (Rostratulidae). Feed the same as rails. These birds probe in the earth to find their food. Worms are essential.

OYSTER CATCHERS (Haematopodidae). They frequent ocean beaches, where they pick up a wide variety of small animal life and perhaps some plant material. In captivity feed small pieces of fish, worms, bread crumbs, green leafy vegetation.

PLOVERS, TURNSTONE, and SURFBIRDS (Charadriidae). Inhabitants of seacoasts and streams, lakes, and ponds. Some live on the drier uplands. Offer a wide variety of fish, meat, grain, green food, bonemeal, crab meat,

crab scraps, or shrimp—all ground, as the mouths of the birds are rather small. Mealworms are particularly relished by the birds.

SNIPE, WOODCOCK, and SANDPIPERS (Scolopacidae). The feeding habits of the snipe and sandpipers are somewhat similar to those of the plover and the turnstones. Woodcocks are specialized feeders that in the wild live largely on earthworms obtained by boring into the ground with their long beaks which have flexible tips that open in the ground, grasp the worm, and pull it out. They are rarely kept in captivity, but a few have survived when fed mealworms or earthworms in earth. Finely cut strips of meat, mealworms, and earthworms might be placed in earth to tempt them.

AVOCETS and STILTS (Recurvirostridae). These beautiful birds inhabit the shores of shallow lakes and alkali ponds. They feed on minute animals such as tiny shrimp, brine shrimp, and other forms; probably they take some plant food as well. They are not known to the author to have been kept in captivity; but it seems probable that they might survive if given mealworms, meat, fish, shrimp, crab, and a variety of green material finely ground and fed in water. The birds spend much time wading and swimming and should be provided with shallow pools and plenty of ground on which to exercise.

PHALAROPES (Phalaropodidae). These little swimming, snipelike birds might thrive on the same mixture suggested for avocets and stilts, but they have rarely, if ever, been kept in captivity.

CRAB-PLOVERS (Dromadidae). Feed same as shore birds.

THICK-KNEES (Burhinidae). Feed a mixture of ground or finely chopped fish, meat, seeds, bread, green vegetation and mealworms.

PRATINCOLES and COURSERS (Glareolidae). Feed same as shore birds.

SEED-SNIPES (Thinocoridae). Feed same as shore birds.

SHEATH-BILLS (Chionidae). The birds of this family have not to our knowledge been kept in captivity. They inhabit the southern shores of the Southern Hemisphere and their habits appear to be somewhat between those of the gulls and petrels. It is possible that they could be successfully kept by offering them mixtures of ground or finely chopped meat, fish, mealworms, shellfish such as clams, crabs, shrimp, and some green food, fed on or in shallow water. They should have pools in which to bathe and swim.

SKUAS and JAEGERS (Stercorariidae). Feed small pieces of meat, mice, small rats, small birds, and fish. They should have a pool in which to bathe.

GULLS and TERNS (Laridae). Feed fish, mice, fruit, meat, bread. Pool for bathing.

SKIMMERS (Rynchopidae). Feed fish and meat. Should have plenty of water for bathing and swimming, and some shore space.

AUKS, AUKLETS, and MURRES (Alcidae). These are heavy-bodied, small-winged seacoast birds that obtain fish and perhaps other food from the sea and usually nest on ledges, in crevices, or in burrows in the ground or under rocks. They are rarely kept in captivity, but should not be difficult to keep. It is suggested that they be fed small strips of fish, squid, and perhaps some shellfish, meats, and shrimp. Young tufted puffins thrived when they were fed from the hand with strips of fish from ¼ to ½ inch in diameter and 2 to 4 inches long that had been dipped in salt water.

The birds should be provided with a pool in which they can swim and dive, and with rocks or ground on which they can rest. They do not need much land on which to exercise. They are not able to take off on the wing from the small areas in which they will normally be enclosed so they can be kept in open-top enclosures, as well as in cages.

SAND-GROUSE, PIGEONS, DOVES (COLUMBIFORMES)

SAND-GROUSE (Pteroclidae). Despite its name, the sand grouse is closely related to the pigeons and doves, both in structure and habits. Like these birds, it will thrive on a mixture of grain and green food. It should be given plenty of gravel or grit.

PIGEONS and DOVES (Columbidae). Grain, small amounts of green leafy vegetation, fruit, and grit are needed by these birds. Many of the tropical pigeons are fruit eaters and should be supplied with grapes, bananas, apples, small pieces of oranges, etc. Raisins might be given if no other fruit is available.

LORIES, PARROTS, AND MACAWS (PSITTACIFORMES)

These birds will eat a considerable variety of food and will thrive on a diet mainly of sunflower and other seeds (such as canary and hemp seed), fruits (such as apples and bananas), bread, carrots, some green food, and some ground meat. Lories, being primarily fruit eaters, will not consume many seeds or much bread. They should have a plentiful supply of fruit, honey, milk, and bread.

All the birds of this group should have limbs or wood on which to bite so that they may keep their beaks properly worn down. Some parrots enjoy bathing, but the grass parakeet (*Melopsittacus*) prefers to roll in wet grass and does not ordinarily bathe in water. Occasionally parrots take to plucking their own feathers to such an extent that they become naked. This probably indicates a dietary deficiency. On occasions it has been remedied by feeding meat and fat or by giving them an opportunity to chew on bones.

In other cases, these methods have been useless. These birds may be kept in moderate-sized cages either alone or in small groups, or in large cages with a variety of other birds. Their cages should be strongly constructed, as they have powerful beaks and will frequently bite persistently at a single place in the cage covering.

Most of these are birds of the Tropics with the exception of a few such as the kea of the high mountains of New Zealand and the grass parakeet (also called budgerigar). These two birds can be kept outside throughout the year in a climate such as that of Washington, D. C. Others must be carefully safeguarded against cold.

PLANTAIN-EATERS AND CUCKOOS (CUCULIFORMES)

PLANTAIN EATERS (Musophagidae). These thrive on bananas, raisins, oranges, grapes, apples, bits of boiled egg, ground meat, mealworms, and mockingbird food.

CUCKOOS, ROADRUNNERS, ANIS (Cuculidae). These birds are insectivorous and carnivorous in their native haunts. The cuckoos should be fed mealworms, ground meat, boiled egg. The roadrunner eats mice, lizards, small birds, and insects, and when these cannot be given, it can be supplied with small pieces of meat and hard-boiled egg.

OWLS (STRIGIFORMES)

BARN OWLS (Tytonidae), OWLS (Strigidae). These are nocturnal birds of prey, and should be fed in the evening. To this rule the snowy owl is an exception. This bird may be fed either in the evening or during the day.

Owls should be supplied with small mammals such as mice and rats, or with birds, such as small chickens. A number of the smaller owls eat insects. They will also eat meat, preferably fragments left on the bone, from which they may tear it off. It is important, however, that they be given plenty of small animals that can be swallowed whole in order that the owls may have the skin, feathers, bones, and viscera. These birds should not be exposed to bright light. It might be possible to reverse their normal round of activities, if they were given very subdued light during the daytime and artificial light at night. They should have an opportunity to get into a box or other cavity or a dark corner to sleep.

OIL-BIRDS AND GOATSUCKERS (CAPRIMULGIFORMES)

OIL-BIRDS (Steatornithidae). Feed mealworms, ground meat, small rodents, insects, reptiles, and possibly hard-boiled eggs.

FROGMOUTHS (Podargidae). A frogmouth has been kept in the National Zoological Park by feeding it one mouse a day. If mice are not available, other food might be offered it, such as mealworms, ground meat, small rodents, insects, reptiles, and possibly hard-boiled eggs.

POTOOS (Nyctibiidae). Same as above.

OWLET-FROGMOUTHS (Aegothelidae). Same as above.

GOATSUCKERS (Caprimulgidae). These birds live by capturing insect prey when on the wing. They are rarely kept in captivity, although a nestling nighthawk that was brought to the National Zoological Park thrived for several years on a diet of mealworms, mockingbird food, and ground meat rolled into small balls. A similar diet might be successful with others of this group and some of the related forms.

SWIFTS AND HUMMINGBIRDS (MICROPODIFORMES)

SWIFTS (Micropodidae). Like the goatsuckers, these birds obtain all their insect food on the wing. They might be successfully kept on food similar to that listed under goatsuckers. Outside cages lighted at night to attract insects have been suggested.

CREST SWIFTS (Hemiprocnidae). Same as above.

HUMMINGBIRDS (Trochilidae). Hummingbirds can be kept in captivity fairly successfully on a mixture of 1 teaspoonful of Mellon's baby food, 2 teaspoonfuls of honey, 1 teaspoonful evaporated milk, 1 drop of beef extract, and 4 teaspoonfuls of water. A convenient feeder is shown in the accompanying diagram (pl. 7, fig. 1). Food containers should be so constructed that these birds can get only their bills in to reach the food. They should also have the opportunity of capturing fruit flies, which can usually be made available to them by leaving a bit of fruit such as a banana in the cage to attract the flies. They will bathe under a fine shower if it is available. They are so small that glass fronts to the cages are desirable. Wire fabric of about ¼-inch mesh can be used on the sides, back, and top. Sunshine or ultraviolet light is necessary in winter.

COLIES (COLIIFORMES)

COLIES (Coliidae). These birds can be successfully kept on a diet of fruit such as bananas, grapes, raisins, oranges, small bits of meat, hard-boiled eggs, mockingbird food, and mealworms.

TROGONS (TROGONIFORMES)

Trogons (Trogonidae). These can be kept on the same diet as the colies.

KINGFISHERS, BEE-EATERS, ROLLERS, AND HORNBILLS (CORACIIFORMES)

KINGFISHERS (Alcedinidae). The North American kingfisher can be fed a diet almost entirely of fish. The tropical kingfishers and those of the other parts of the world feed on a wide variety of animal life such as large insects, lizards, and fish. The kookaburra of Australia is included in this group. They should be fed mice, worms, lizards, and small birds, such as finches. The birds vary greatly in size, and the smaller kingfishers cannot, of course, take full-grown mice or lizards.

TODIES (Todidae). May be fed hard-boiled eggs, small bits of meat, mealworms, bananas, oranges, and raisins.

MOTMOTS (Momotidae). Same as for todies.

BEE-EATERS (Meropidae). In the wild, these birds eat insects and are particularly fond of bees, apparently suffering no ill effect from stings. In captivity, they should be offered as wide a variety of insects as can be obtained, such as mealworms and grasshoppers, as well as finely ground meat, boiled egg, and mockingbird food.

ROLLERS (Coraciidae). Same as for motmots.

CUCKOO-ROLLERS and GROUND-ROLLERS (Leptosomatidae). Mostly insectivorous. Feed mealworms, grasshoppers, meat, boiled egg, mockingbird food.

HOOPOES (Upupidae). The hoopoes will thrive on the same food recommended for the bee-eaters.

WOOD-HOOPOES (Phoeniculidae). Feed same as bee-eaters (Meropidae).

HORNBILLS (Bucerotidae). Hornbills thrive on a diet of mockingbird food rolled with boiled rice into balls about the size of marbles; also balls of meat, bananas, grapes, oranges, apples, pears, boiled egg. Mice, lizards, or small birds are essential to their welfare.

JACAMARS, BARBETS, TOUCANS, AND WOODPECKERS (PICIFORMES)

JACAMARS (Galbulidae). Feed insects, mealworms, mockingbird food, boiled eggs.

PUFF-BIRDS (Bucconidae). Same as above.

BARBETS (Capitonidae). These birds will thrive on the same diet as that recommended for hornbills. Balls of food must be made much smaller than those given to the hornbills.

HONEY-GUIDES (Indicatoridae). Feed insects, mealworms, mockingbird food, boiled eggs.

TOUCANS (Ramphastidae). They thrive on the food recommended for hornbills. Make the balls of food smaller.

WOODPECKERS and PICULETS (Picidae). Rarely kept in captivity. In the wild they feed on insects, ants, fruit, acorns, and some other plant food. In captivity they can be given mealworms, meat, suet, fruit, and should be offered some bread, grain, hard-boiled eggs, and mockingbird food. Most of these birds regularly cling to the sides of trees and should have rough-barked limbs in a more or less vertical position to which they may cling. They will also perch crosswise on larger limbs, but do not care for small perches.

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PERCHING BIRDS (PASSERIFORMES)

BROADBILLS (Eurylaimidae). Feed fruit, bananas, oranges, apples, grapes, boiled eggs, mockingbird food.

WOOD-HEWERS (Dendrocolaptidae), OVENBIRDS (Furnariidae), ANT-THRUSHES (Formicariidae), ANT-PIPITS (Conopophagidae), TAPACULOS (Rhinocryptidae). The birds of these families are known as soft-billed birds, and will eat fruit, mockingbird food, boiled egg, and mealworms and other insects. Live worms and insects are essential.

COTINGAS, BELL-BIRD, COCK-OF-THE-ROCK (Cotingidae), MANAKINS (Pipridae). Feed fruit, boiled egg, mockingbird food.

TYRANT FLYCATCHERS (Tyrannidae). Aerial feeders in the wild, and difficult to keep in captivity. Feed mealworms, ground meat, boiled egg, mockingbird food. Insects are almost essential.

SHARP-BILLS (Oxyruncidae), PLANT-CUTTERS (Phytotomidae). Same as above.

PITTAS (Pittidae). Feed mealworms and any other available insects, mockingbird food, and ground meat. The floor of the cage should be covered with soft material, as their feet are tender.

NEW ZEALAND WRENS (Acanthisittidae), ASITIES (Philepittidae). Feed insects, mealworms, mockingbird food, boiled egg.

LYRE BIRDS (Menuridae). Feed fruit, insects, seeds, and green vegetation. They spend much of their time on the ground.

SCRUB-BIRDS (Atrichornithidae). Soft-billed birds. Feed the same as thrushes.

LARKS (Alaudidae). Feed mockingbird food, mealworms, boiled eggs, ground meat, fruit, lettuce.

SWALLOWS (Hirundinidae). Give them mealworms and any other available insects, also ground meat. Try bread, soft, well-ripened fruit, and cheese. These birds are rarely kept in captivity, and no method is known to be particularly successful with them.

CUCKOO-SHRIKES (Campephagidae). Soft-billed birds. Feed meat, mockingbird food, insects boiled egg.

DRONGOS (Dicruridae), OLD WORLD ORIOLES (Oriolidae). Feed mealworms and other insects, ground meat, mockingbird food, fruit, boiled egg. Insects are essential.

CROWS, MAGPIES, JAYS (Corvidae). These omnivorous birds thrive in captivity if given a wide variety of meats, soaked grain, bread, fruit, vegetable material. They enjoy mealworms, insects, and mice; some of them will eat small birds.

BIRDS OF PARADISE (Paradiseidae). Feed mockingbird food with liberal addition of grated carrots and boiled eggs, apples, raisins, bananas, oranges, meat, insects. When the birds are growing new plumage, they apparently become greatly exhausted. At such times they should have ant eggs and plenty of insects.

PARROT-BILLS, SUTHORAS (Paradoxornithidae). Soft-billed birds. Feed same as thrushes.

TITMICE (Paridae), NUTHATCHES (Sittidae). Feed mockingbird food, boiled eggs, ground meat, mealworms, seeds, soft nuts, bread, meat, insects.

CORAL-BILLED NUTHATCHES (Hypositidae). Soft-billed birds. Feed mealworms and other insects, ground meat, bread, fruit, and tender green leaves.

CREEPERS (Certhiidae). Feed mealworms, other insects, and ground meat.

WREN-TITS (Chamaeidae). Soft-billed birds. Feed same as thrushes.

BABBLING THRUSHES (Timaliidae). Feed mockingbird food, mealworms, and other insects, ground meat, fruit, lettuce, raisins, grapes.

BULBULS (Pycnonotidae). Fruit, insects, mockingbird food, ground meat, bread crumbs, boiled eggs, canary seed.

DIPPERS (Cinclidae). Not known to the author to have been kept in captivity. Frequent streams, into which they dive to capture aquatic insects. Try feeding mealworms, waxworms, and any other insects available, and ground meat. Also lettuce and soft green vegetation. Should have water in which to bathe; preferably a continuous shower falling into a small stream or pool, which might make them feel more at home.

WRENS (Troglodytidae), MOCKINGBIRDS and THRASHERS (Mimidae), THRUSHES (Turdidae). Feed fruit, mockingbird food, boiled eggs, mealworms and other insects, ground meat, some green food, bread crumbs.

OLD WORLD WARBLERS (Sylviidae), KINGLETS (Regulidae), OLD WORLD FLYCATCHERS (Muscicapidae), ACCENTORS, HEDGE-SPARROWS (Prunellidae), WAGTAILS, PIPITS (Motacillidae),WAXWINGS (Bombycillidae). Feed mealworms or any other insects available, and ground meat. Also try soft, well-ripened fruit and a small amount of bread crumbs. Rarely kept in captivity, and no well-proved diets are known to the author.

SILKY FLYCATCHERS (Ptilogonatidae). Aerial feeders. Try mealworms and any other insects, also mockingbird food, boiled eggs, and ground meat.

PALM-CHATS (Dulidae), WOOD-SWALLOWS (Artamidae), VANGA SHRIKES (Vangidae). All insect eaters. Feed soft food, meat, mealworms, flies, small animals.

SHRIKES (Laniidae). Feed mealworms and any other insects available, also meat, mice, small birds, mockingbird food, boiled eggs, bread, lettuce.

WOOD-SHRIKES (Prionopidae), PEPPER-SHRIKES (Cyclarhidae), SHRIKE-VIREOS (Vireolaniidae). All insect eaters. Feed soft food, meat, mealworms, flies, small animals.

STARLINGS (Sturnidae). Feed the same as crows and jays.

HONEY-EATERS (Melithreptidae), SUN-BIRDS (Nectariniidae), FLOWER-PECKERS (Dicaeidae), WHITE-EYES (Zosteropidae). Feed mealworms and other insects, ground meat, mockingbird food, boiled egg, fruit. Some of these birds like honey.

VIREOS (Vireonidae). Feed mealworms and other insects, ground meat, fruit, mockingbird food.

HONEY-CREEPERS (Coerebidae), HAWAIIAN HONEY-CREEPERS (Drepanididae). Feed fruit, such as oranges, bananas, apples, with honey, mealworms and other small insects. If flowers are in the cage, they will thrust their long, curved beaks into the flowers to obtain the nectar. Orange and pineapple juice in small tubes might be accepted.

WOOD-WARBLERS (Compsothlypidae). Insect eaters in the wild. Feed mealworms, small insects, ground meat, and well-ripened soft fruit. Rarely kept in captivity, and no tested diet is known to the author.

WEAVER FINCHES (Ploceidae), BLACKBIRDS, TROUPIALS (Icteridae). Feed seeds, bread, fruit, green vegetation, vegetables, mealworms and other insects, and ground meat.

SWALLOW-TANAGERS (Tersinidae). Feed mockingbird food, boiled eggs, fruit, mealworms and other insects.

TANAGERS (Thraupidae). Feed soft ripe fruit, such as bananas and oranges, mockingbird food, mealworms and other insects, boiled eggs, and lettuce.

PLUSH-CAPPED FINCHES (Catamblyrhynchidae). Feed mockingbird food, boiled eggs, mealworms and other insects, green vegetation, seeds, and fruit.

GROSBEAKS, FINCHES, BUNTINGS (Fringillidae). Feed assorted seeds, fruit, lettuce, and other green vegetation, mealworms, ground meat.

REPTILES

Reptiles are known as cold-blooded animals because their temperature fluctuates with that of their surroundings. They are mainly creatures of warm climates, and must be kept warm to be active. When the temperature gets low, they become sluggish and torpid, like other hibernating animals. If they are continuously subjected to daily warming and nightly chilling, they will refuse to eat, and, while they mey be active during the daytime, they will become weak and presently die. It is therefore important that they be given a fairly constant and uniform temperature within the range preferred by the species. In general, the temperature for reptiles should not go below 70° and the animals will be more active and interesting at a temperature of 80° to 90° or upward. Cages for reptiles should be provided with some means of warming such as electrical heating units controlled by thermostats, or other devices that will aid in maintaining a fairly constant temperature at all times. A convenient means of providing uniform temperature for those animals that burrow is a thick layer of sand that can be warmed and that will retain the heat.

Almost all reptiles need plenty of sunshine, or the substitute, ultraviolet light. However, they cannot endure extremes of either light or heat.

Most snakes drink frequently and should be provided with water. Some lizards drink, others do not even though there is an abundance of water available, as nature has provided that they shall take moisture through their skins. These animals should be sprinkled with water occasionally, or placed in a shallow pan of water.

The shedding of skin by snakes and lizards is facilitated if the animals have access to water in which to soak. In some instances, gentle manipulation assists shedding.

Some reptiles and amphibians will not notice food that is not moving. Therefore, if an individual will not eat when all other conditions seem to be suitable, try impaling the food on a stick and moving it about in front of the animal. This procedure is sometimes successful.

ALLIGATORS, CROCODILES, CAIMANS AND GAVIALS (LORICATA; CROCODYLIDAE)

All of these thrive on fish or meat, or both. If the temperature is maintained at 75° to 100°, and they refuse to eat at least once a week, they can sometimes be tempted by placing the fish or meat on the end of a stick and annoying them until they snap at the food. By this method they can sometimes be induced to eat freely. Provide with a pool of water of about air temperature into which the food can be thrown. There should be earth or rocks upon which they may climb to bask in the sunshine or the rays of powerful electric lights. They are not particularly active and do not require much space to exercise.

TURTLES, TORTOISES, AND TERRAPINS (TESTUDINATA)

The baby turtles often sold with gaudily painted shells never develop properly, as the paint stunts their growth and eventually kills them. The paint may be removed by swabbing with turpentine or alcohol, but these fluids should not be allowed to come in contact with the young turtle's skin.

LEATHERBACK TURTLES (Dermochelidae). Feed fish. They must have fair-sized tanks of salt water of about 85° to 95° Fahrenheit. In the wild state, they come out of the water only to lay their eggs, so will not need any area above the water unless the females are to be encouraged to lay their eggs in the sand. They may be kept for a limited time in fresh water, but where so kept they usually succumb within a short time. See formula on page 330 for making salt water. Water should be changed sufficiently often to keep the tank from becoming cloudy, but need not be changed as often as for some other animals.

If whitish films develop around the eyes, it is ordinarily a fungus growth and is usually fatal. Sometimes this condition can be controlled by the following methods:

Add enough potassium permanganate to the water to give a slight tinge of color. The animals should be placed in this for 3 days, then in plain salt water for 1 day, changing again to the permanganate bath for 3 days, next remaining for 9 days in clean salt water, again 3 days in the permanganate water, then finally remaining in salt water. This latter method is used in some aquaria to kill various invertebrates as well as fungi.

Another method is to add about 1 ounce of tincture of iodine to each 10 gallons of water in the tank.

Chlorine in the proportion of ½ to 2 parts per million of water will also kill fungi. Care should be exercised not to make the solution so strong as to injure the turtles or fish.

SNAPPING TURTLES and ALLIGATOR SNAPPERS (Chelydridae). Feed fish or meat. Provide with sufficient water in which to swim, and earth, sand, or rocks on which they can rest when out of the water.

MUSK or MUD TURTLES (Kinosternidae). Feed fish and meat. They should have water in which to swim and some ground, rocks, or other space above the water on which to rest.

LARGE-HEADED CHINESE TURTLE (Platysternidae). Will eat meat, snails, worms, and fish. Usually lives in mountain streams. Nocturnal.

BOX TURTLES, LAND TORTOISES, and many FRESH-WATER TURTLES (Testudinidae). The land forms need plant food such as lettuce, kale, bananas, melons, prickly pear cactus, mushrooms, tomatoes, and occasionally a little fish or ground beef and soft bread. The aquatic types should be fed fish, meat, insects, shrimp, some green vegetation, fruit, and bread. Provide sufficient water in which to swim, and space to roam about out of the water. Some of the dry-land forms do not swim, and will drown in water. If one is not certain of the swimming or water requirements of this group, it is well to provide the cage with a tank with sloping edges so that the animal can readily climb out of water. The dry-land forms enjoy soaking in shallow water, as they may obtain their water in this manner rather than through drinking.

SNAKE-NECKED TURTLES (Pelomedusidae). Fish, meat, and insects should be offered; also occasionally lettuce, bananas, and bread, until one is certain the individuals he has will or will not take it. Since they are semiaquatic, they should have water in which to swim; also a fair amount of area outside

the water. It is said that some of these turtles cannot swallow unless they have their heads beneath the water. The writer has seen them take cockroaches beneath the water to swallow them.

WATER-TURTLE OF NEW GUINEA (Carettochelys). Habits unknown. Supposedly like those of other fresh-water turtles. (See Testudinidae—aquatic types.)

SOFT-SHELLED TURTLES (Trionychidae). Fish and meat appear to be adequate foods. These turtles spend most of their time in the water or mud, but enjoy sunning themselves, so in addition to an ample swimming tank, they should have a place to rest above the water.

LIZARDS AND SNAKES (SQUAMATA)

LIZARDS (SUBORDER SAURIA)

GECKOES (Gekkonidae). Tropical animals. Keep warm. Feed cockroaches, mealworms, and other insects.

CAT-EYED GECKOES (Eublepharidae). Nocturnal. Feed insects.

BARK GECKO (Uroplatidae). Habits presumably same as those of the true geckoes. Try similar food.

"WORM" LIZARD (Pygopodidae). Habits not known. Try feeding earthworms, enchytrae, and insects.

AGAMAS and their allies (Agamidae). Ground-dwelling and arboreal. Feed insects, fruit, meat, tender green leaves.

IGUANAS and their allies (Iguanidae). Small species eat insects and small invertebrates. Large forms devour birds and small mammals, and rob birds' nests. The marine iguana of the Galápagos Islands feeds on seaweed. The common iguana of tropical America is largely herbivorous. Feed fruit and green vegetation. The chuckwalla of the southwestern United States eats cactus and other flowers. Feed flowers, buds, and green vegetation. Some desert forms, such as the horned lizard (horned "toad"), need sand in which to burrow. Feed ants and other insects.

XENOSAURUS (Xenosauridae). Related both to the Iguanidae and the Anguidae. Food habits are presumably the same.

ZONURUS (Zonuridae). Feed ground meat, boiled egg, and lettuce.

SLOW-WORMS, ALLIGATOR LIZARDS, and their allies (Anguidae). The burrowing forms feed on small earthworms, enchytrae, and possibly slugs. The more active terrestrial ones catch insects. Feed enchytrae, mealworms, waxworms, other insects, and meat.

"WORM" LIZARD (Anniellidae). Burrowing. Feeding habits probably similar to Anguidae. Provide with earth.

GILA MONSTERS (Helodermatidae). Feed eggs mixed with raw chopped beef. Will sometimes take mice.

MONITORS (Varanidae). Feed mice, rats, lizards, snakes, fish, birds, meat, eggs. Extremely voracious.

NIGHT LIZARDS (Xantusiidae). Feed same as Teiidae (next family).

RACE-RUNNERS and their allies (Teiidae). The small species eat insects, mealworms, grubs, grasshoppers, crickets, and other invertebrates of suitable size. Large ones, such as the tegus, devour young chickens, eggs, raw meat, and rats.

"WORM" LIZARDS (Amphisbaenidae). Burrow in sand or soil. Feed earthworms, enchytrae, and raw beef.

WALL LIZARDS (Lacertidae). Insectivorous. Some are cannibalistic. Feed insects, meat, boiled eggs, and lettuce.

GERRHOSAURUS (Gerrhosauridae). Presumably insectivorous. Try mealworms, waxworms, small mice, and lettuce.

SKINKS (Scincidae). Feed insects, worms, slugs, meat, and fruit. The stump-tailed lizard is known to eat meat, lizards, and snakes. The smaller species are satisfied with insects and slugs.

ANELYTROPSIS (Anelytropidae). Feeding habits not known to the author.

DIBAMUS (Dibamidae). Blind, subterranean. Try enchytrae, earthworms, and soft insects. Provide earth in which it can burrow.

CHAMELEONS (Chamaelontidae). Feed grasshoppers, crickets, spiders, flies. Provide plants or limbs on which the animal may climb.

SHINISAURUS (Shinisauridae). Feeding habits not known to the author.

SNAKES (SUBORDER SERPENTES)

BLIND SNAKE or WORM SNAKE (Typhlopidae). Burrows. Feed earthworms, enchytrae, soft insects, mealworms, fly larvae, maggots, and waxworms. Provide earth in which it can burrow.

BLIND SNAKE or WORM SNAKE (Leptotyphlopidae). Same habits as Typhlopidae.

SHIELD-TAILED SNAKE (Uropeltidae). Burrows. Feed on earthworms, enchytrae, and insect larvae.

SUN-RAY SNAKE (Xenopeltidae). Eats other snakes. Provide earth for burrowing.

BOAS and PYTHONS (Boidae). Feed mice, rats, rabbits, pigs, pigeons, and chickens. Some will eat other reptiles.

ANILIUS (Anilidae). Eats other snakes. Provide earth in which to burrow.

COLUBRID SNAKES (Colubridae). About 1,200 different species. This family includes most of the harmless snakes, as well as venomous rear-fanged serpents. Feed mice, rats, small birds, eggs, insects, frogs, toads, and fish.

COBRAS, CORAL SNAKES, KRAITS (Elapidae). Feed mice, rats, birds, snakes. The coral snake eats smaller snakes and baby mice.

SEA SNAKES (Hydrophidae). These snakes inhabit tropical seas. Feed eels or strips of fish. Keep in tanks of warm salt water.

CHUNK-HEADED SNAKES (Amblycephalidae). Feed snails and slugs. If these are not available, try mealworms, waxworms, baby mice, and meat.

TRUE VIPERS (Viperidae). Feed mice, small rats, and small birds.

RATTLESNAKES, WATER MOCCASINS, COPPERHEADS, FER-DE-LANCE, BUSHMASTER (Crotalidae). Feed mice, small rats, small birds. Moccasins also take fish.

AMPHIBIANS

Amphibians are cold-blooded but do not require such high temperatures as reptiles and cannot endure drying conditions, for their skin is moist and evaporation takes place rapidly. They will dry up and die if they do not have water, mud, moist vegetation, or other similar materials in which to harbor. Temperatures for salamanders generally should not exceed 90°, and many of these animals thrive best under temperatures of about 70°. Some will remain active in temperatures as low as 40°, but below that point will become torpid, as for hibernation. Shade is necessary.

Tadpoles (immature stage of most amphibians) are aquatic. They feed on the green scum and microscopic plant life found in standing water. This material must be provided if they are to survive in aquaria.

FROGS AND TOADS (SALIENTIA)

NEW ZEALAND FROG (Liopelmidae). Semiaquatic. Should have both water and a bank of mud or sand on which they can come out. Feed earthworms, small insects, scraps of raw beef moved about in front of them.

DISCOGLOSSUS (Discoglossidae). Eats earthworms dropped into water. Semiaquatic, so should have pool and mud bank.

SURINAM TOAD and its allies (Pipidae). Feed scraps of raw fish or meat and mealworms dropped into water. Aquatic, so must have tank of water.

PELOBATES and its allies (Pelobatidae). Feed worms, slugs, and insects, especially beetles. Burrows, so should have soil in cage.

TOADS and their allies (Bufonidae). Must have moist soil and water. Feed mealworms, cockroaches, or any crawling insects, spiders, and earthworms. Some keepers have observed that where two or more species of toads or frogs have been put together, there have been unusual losses. This suggests that it may be advisable to keep each species to itself.

TOADLIKE AMPHIBIANS (Brachycephalidae). A mixed group. Feed as for Ranidae (below).

TREE TOADS (Hylidae). Feed soft-bodied insects, preferably alive, and provide plants in the cage so that the animals can rest on the foliage.

TRUE FROGS (Ranidae). Feed live insects to the small and medium-sized. Some of the larger frogs will take small mice.

ASIATIC TREE TOADS (Polypetidae). Give same food as Hylidae.

NARROW-MOUTHED TOADS (Brevicapitidae). Feed earthworms, slugs, ants, and other small invertebrates. Burrows, so should have soil in cage.

SALAMANDERS (CAUDATA)

COECILIANS (Coeciliidae). Legless, wormlike creatures that live in the moist soil, mud, or swamps of the Tropics. Try earthworms, enchytrae, and soft-bodied insects.

HYNOBIUS (Hynobiidae). Try earthworms, enchytrae, and small incects.

GIANT SALAMANDER, HELLBENDER, and allies (Cryptobranchidae). Inhabit clear streams of fairly cool water. They possess neither lungs nor gills and obtain the necessary oxygen from the water through their skins. Therefore, they should be provided with well-aerated water in a pool or tank. Feed worms, insects, meat, liver, boned fish.

SPOTTED SALAMANDER and allies (Ambystomidae). Feed earthworms, enchytrae, mealworms, waxworms, and soft-bodied insects.

MUD-"EEL," BLIND EEL, CONGO SNAKE (Amphiumidae). Inhabitants of sluggish, warm streams, where they spend much time in the mud. Provide with mud in the bottom of the aquarium, if possible, and feed mealworms enchytrae, soft-bodied insects, and small particles of meat.

SLIMY SALAMANDER and allies (Plethodontidae). Must have moist soil and water. Feed earthworms, enchytrae, slugs, small insects, and small pieces of meat moved in front of them on the end of a straw.

CAVE SALAMANDERS (Proteidae). The white or colorless cave salamander of the United States and Europe (Proteus) is accustomed to cool water in almost

total darkness. Feed sparingly on enchytrae, ground shrimp, daphnia, waxworms, or bits of raw meat. *Necturus*, the two North American colored forms, inhabit warm, sluggish streams. Feed fish eggs, enchytrae, mealworms, small bits of fish, and acquatic insects.

SIREN (Sirenidae). Feed small fish, fish eggs, tadpoles, aquatic insects or their larvae, enchytrae, earthworms. Aquatic, so should have pool of water.

FISH

Fish kept in captivity for exhibition purposes may be roughly divided into two classes, as follows:

Small, mainly tropical fish, often beautiful, brilliantly colored creatures, can be kept in small aquaria without inconvenience, and sometimes add real beauty to the home. Great interest has been taken in so-called tropical fish raising, and some excellent publications have been issued on the subject. (See bibliography.)

Larger fish require large tanks with special provisions for aeration, filtering, cooling or warming the water, and to keep them involves numerous problems which only a large aquarium could undertake. It is therefore not advisable to attempt to treat the keeping of fish in this work.

Such large aquaria as the John G. Shedd Aquarium, Chicago, the Aquarium of the New York Zoological Society, New York City, the Steinhardt Aquarium, San Francisco, the Regents Park Aquarium operated by the Zoological Society of London, and numerous others have issued publications relative to the raising of fish. The United States Bureau of Fisheries, now a part of the United States Fish and Wildlife Service, Department of the Interior, has issued many publications relating principally to commercial fish. In addition, many facts are contained in articles and reports issued through various biological laboratories.

INVERTEBRATES

There are a vast number of invertebrates, including protozoa, worms, soft-bodied marine forms, crabs and crayfish, insects and mollusks that are attractive to many people. Many of these make interesting and sometimes beautiful exhibits, but a discussion of their care is beyond the scope of this paper. Information regarding the keeping of such creatures can be obtained from entomologists or other biologists. The raising and study of such forms can be a fascinating work or hobby for persons who are interested.

LITERATURE RELATING TO THE CARE OF ANIMALS

A vast amount of material on the subject of animals and their care has been written. It is not possible to give here even a reasonably complete list of such literature. Governmental agencies of practically all countries throughout the world have issued publications on domestic and wild animals. In our own country, the United States Fish and Wildlife Service, of the Department of the Interior, has many bulletins and leaflets on North American birds, mammals, reptiles, amphibians, and fish, some of which treat of the raising of fur-bearing animals, certain birds, fish, and invertebrates. Scientific societies and various research agencies have put out many excellent works. Natural histories and similar works—dealing specifically

with certain animals, groups of animals, or the animals of certain regions—and encyclopaedias contain much information of value to those interested in the care of animals. Periodicals on fur farming, aviculture, and general natural history contain many articles of interest to one keeping pets. A few of these works are cited below, not because they are necessarily the best, but because they are readily accessible, or known to the author to be useful.

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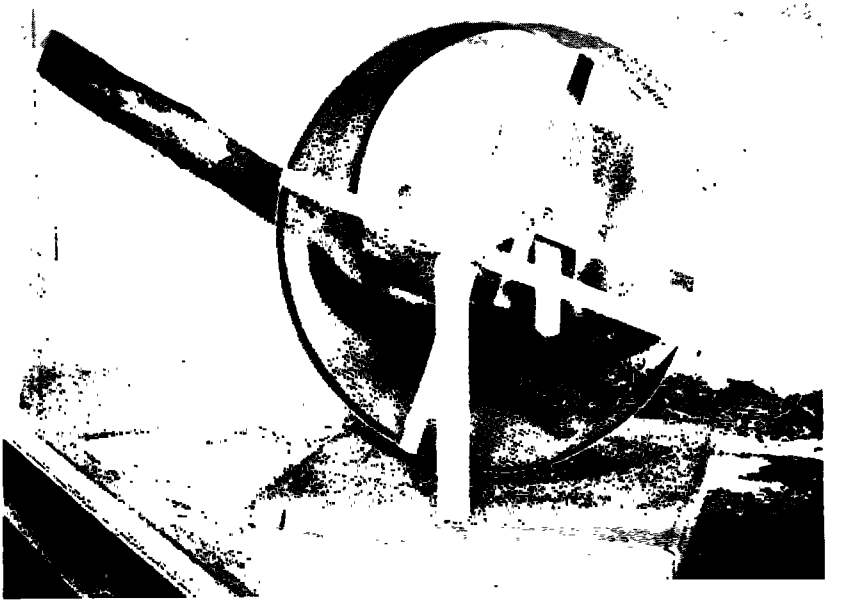
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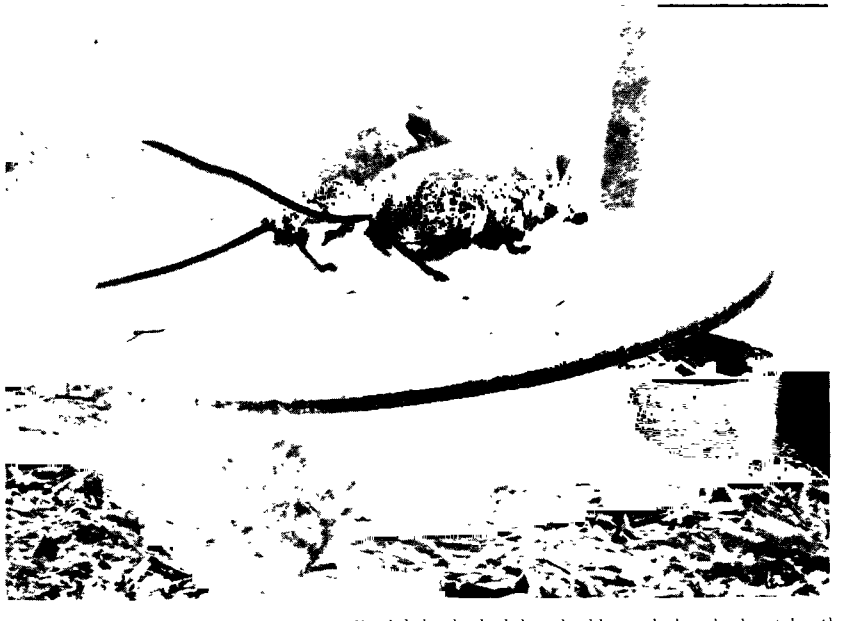
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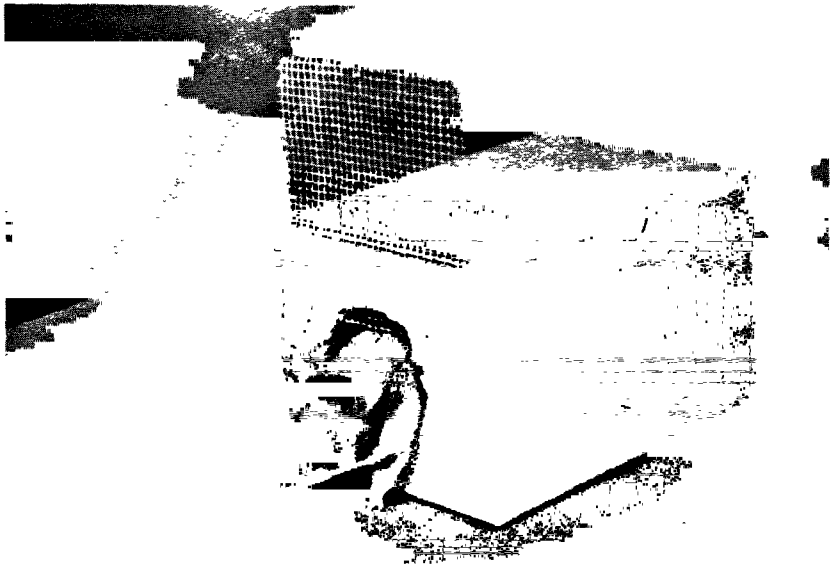


1 A choice specimen of American mink running a ferris-type wheel in its glass-fronted cage. A small stump and limb on which the animal can climb is behind the wheel



2 Two big-eared cliff mice running on an inclined disk wheel while a third beneath the wheel watches the photographer.

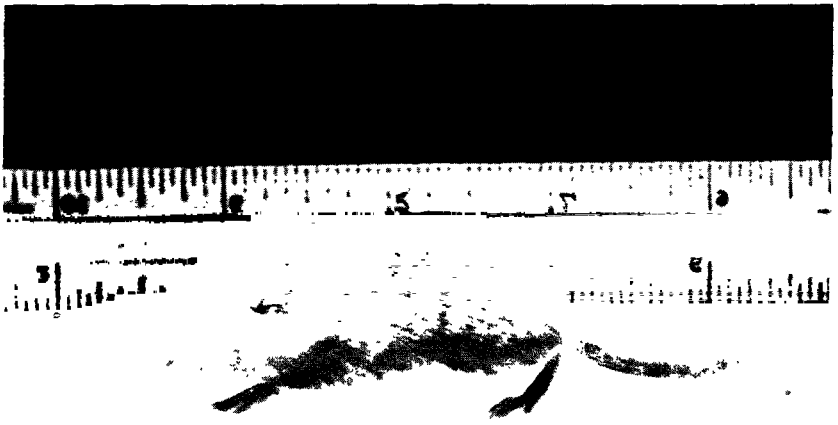
All photographs taken by the author unless otherwise indicated



2. Syrian hamster coming out of a telescoping type of nest box, showing wire fabric slide used to close the entrance when desired



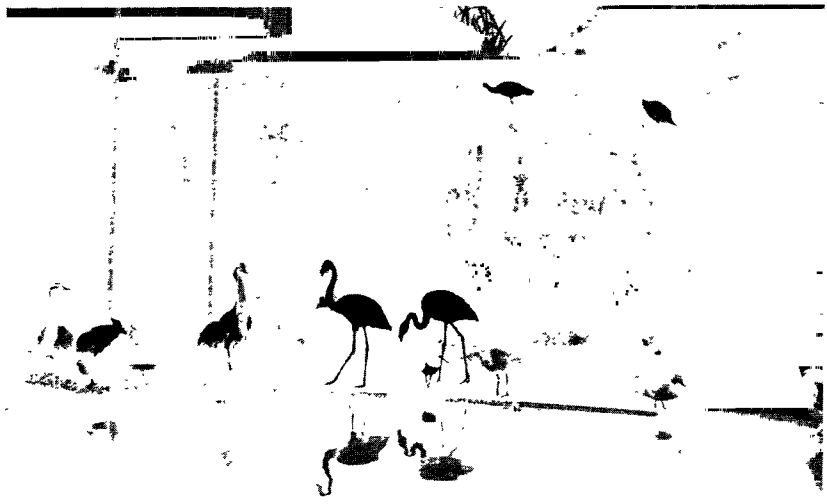
2. Three emperor penguins, one gentoo penguin, four jackass or black-footed penguins, and two kelp gulls in glass-fronted cool room in the National Zoological Park. The glass front is of two layers of glass with a dead air space between. A temperature of about 50° is maintained



1. Plains pocket mouse with fur in good condition as the result of cleaning her coat in very fine dry sand.



2. Plains pocket mouse with fur beginning to show bad condition, owing to having been on coarse sawdust for 72 hours. The cracked appearance in the fur is the result of the sticking together of the hairs, partly by the oily secretion of the skin and partly by the resinous material in the sawdust.



1 Scene in flight cage in bird house, National Zoological Park, showing Chilean flamingoes, demoiselle cranes, scarlet ibis, Egyptian ibis, white ibis, black-billed tree ducks, Chilean pintail, gallinules, American coot, European oyster catchers, fireback pheasant, Chilean lapwing, sun-bittern, wood pigeon, golden pheasant, New Zealand mudhen.



2 Waterfowl on one of a series of four ponds, National Zoological Park. About 30 species of waterfowl are usually in this enclosure. Whistling swans, snow geese, blue geese, Hutchins geese, pintail ducks, canvasbacks, mallards, blue-wing teal, wood ducks, Pekin ducks, and coots appear in this scene



1. Aoudads or barbary sheep at artificial mountain in National Zoological Park.



2 Alaska brown bears on artificial rock work in Brookfield Zoo, Chicago, Ill., separated from the public by a moat.



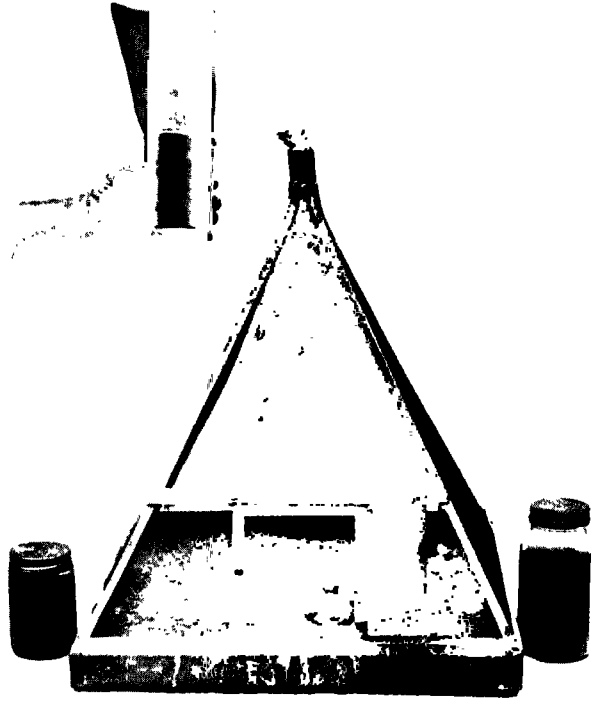
1 Woodchuck or marmot that was almost nude for several years, apparently because of a dietary deficiency. After 4 months on a suitable diet it grew a heavy coat of hair Photograph by C P. Richter



2 Pinche tamarin in glass-fronted cage in small-mammal house, National Zoological Park



1. Hummingbird feeder tube. About 1 inch in diameter and 4 inches long.



2. Fly trap and breeding cage, showing open door and a dead fish on the sawdust in the bottom of the cage. The jars on either side show fly pupae and maggots that have been produced. They can be fed at once, or the pupae place in cold storage to be taken out and hatched when needed.



1 Skull of marmot or woodchuck with both upper and lower incisors grown so long that the animal could not gnaw or eat normally The left upper incisor had penetrated the roof of the mouth.



2 Left, end of tail of coypu or nutria, probably originally injured by fighting, but worn to the bone at the tip by dragging on concrete; right, foot of ring-tailed monkey or capuchin, showing area on bottom of heel from which the skin and flesh had been worn to the bone as a result of walking on the concrete floor The animals give no evidence of pain caused by such injuries.



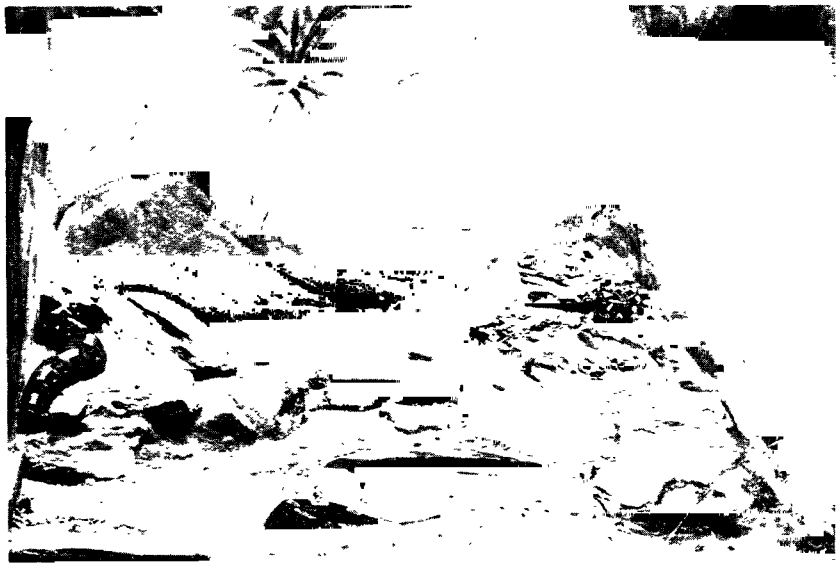
1 Malayan porcupines gnawing on a freshly cut tulip tree limb about 20 inches long and 4 inches in diameter Within 10 hours, the five porcupines in this cage had reduced the limb to a mass of chips and a spindle-shaped piece about a foot long and not more than 2 inches in diameter at its largest point



2 Binturong on artificial rock work in Brookfield Zoo, Chicago, Ill., separated from the public by a moat and a low, irregular imitation rock wall.



Reptile pool in yard enclosed by moat, low fence, and guard rail, in front of reptile house, National Zoological Park



1 Three gaboon vipers in glass-fronted cage in reptile house, National Zoological Park A small pool is immediately beyond the snake closest to the glass in front



2 American alligators in glass-fronted room in reptile house, National Zoological Park A skylight comprises almost the entire roof Both plants and alligators thrive in the temperatures of 80° to 100°, and the high humidity that prevails in this enclosure.



1 Horned lizards and fence lizards in cage with clear-glass front, pebble-glass sides, back, and top, a small cactus, and an artificial rock with a hollow in the top for water



2. Argentine horned frog in cage in reptile house, National Zoological Park. The sides and back of the cage are of pebble glass, with front of clear glass. A small pool shows in the background.

THE INFLUENCE OF INSECTS ON THE DEVELOPMENT OF FOREST PROTECTION AND FOREST MANAGEMENT[1]

By F. C. CRAIGHEAD

Principal Entomologist, Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine

[With 12 plates]

Forty years ago, when the idea of forest conservation was acquiring momentum, few people realized that insects were in any manner a part of this picture. Today, with our coordinated Federal, State, and private organizations for the protection of our forest properties, over a million dollars are expended annually in measures designed to protect these forests from insect depredations. At the same time the cooperative efforts of a group of highly trained entomologists, pathologists, and foresters are devoted to the development of plans for growing new timber crops so as to circumvent the numerous forest pests of our second-growth forests.

EARLY INSECT OUTBREAKS

There are historical records of several destructive insect outbreaks, both bark beetles and defoliators, in earliest colonial times. These early affairs appear to have been regarded as more beneficial than injurious, coming as they did when the dense forests were a handicap to settlement and farm expansion.

Probably the first insect outbreak that aroused sufficient concern among lumbermen to give rise to technical investigation occurred in West Virginia, Virginia, and Maryland from 1890 to 1892 from attacks of the southern pine beetle (*Dendroctonus frontalis* Zimm.) A. D. Hopkins (1899) studied this outbreak in great detail and reported on it in a publication of the West Virginia Agricultural

[1] Investigations on forest insects by the Bureau of Entomology and Plant Quarantine are carried on at nine field laboratories. Their leaders and locations are as follows: R. C. Brown, New Haven, Conn.; C. W. Collins, Morristown, N. J.; J. C. Evenden, Coeur d'Alene, Idaho; C. H. Hoffman, Ashville, N. C.; F. P. Keen, Portland, Oreg.; H. J. MacAloney, Milwaukee, Wis.; J. M. Miller, Berkeley, Calif.; D. E. Parker, Columbus, Ohio; T. E. Snyder, New Orleans, La. Substations are also located at Saucier, Miss., Miami and Hat Creek, Calif., Cass Lake, Minn., La Grande, Wash., and Beltsville, Md. Many unpublished reports from these laboratories were drawn upon for the factual material used in this presentation.

Experiment Station. In an area of over 75,000 square miles a large percentage of the pine and spruce was killed. A few years later, around 1900, the eastern spruce beetle (*D. piceaperda* Hopk.) was responsible for extensive depredations in the forests of Maine. Here again Hopkins (1901), collaborating with Austin Cary (1900) of the Forest Service, made a study of the conditions. Just prior to and during the Maine outbreak, 1895–1905, the Black Hills beetle (*D. ponderosae* Hopk.), which was not known to science at this time, destroyed more than a billion feet of timber in the Black Hills National Forest in South Dakota (Hopkins, 1902). This outbreak crystallized the realization that more technical knowledge was needed concerning these destructive bark beetles, and resulted in a small appropriation of $5,800 for the Bureau of Entomology for forest insect investigations and an allotment of $2,700 in 1906 for the control of this outbreak.

WESTERN BARK BEETLES

Recent outbreaks of bark beetles have been even more widespread and spectacular. To quote from a recent unpublished report of F. P. Keen, in charge of our Portland, Oreg., laboratory:

> The ponderosa pine forests of the Pacific States have suffered a continuous and serious drain from western pine beetle attack for the past 20 years or more, while in the Rocky Mountain region sporadic outbreaks of the Black Hills beetle have taken a heavy toll of this species of pine in many local areas. Most spectacular of all has been the destruction of lodgepole pine forests in the northern Rocky Mountain region and local areas in the Cascades from uncontrolled outbreaks of the mountain pine beetle. Sugar pine [pl. 2, fig. 1; pl. 4], western white pine, and other species of pine are from time to time also seriously damaged by pine beetles.
>
> Records from annual surveys in the Klamath region of southern Oregon and northeastern California show that on an area of 4,300,000 acres 5,273,000,000 board feet of ponderosa pine timber, representing 17.5 percent of the stand, was killed during the 20-year period 1921 to 1940 inclusive. This, of course, is not all a direct loss, as some of it was offset by growth. In portions of this region from 60 to 90 percent of the stand was destroyed. The western pine beetle (*Dendroctonus brevicomis* Lec.) was a major factor in this mortality. [Pl. 2, fig. 2.]
>
> An outbreak of the Black Hills beetle (*Dendroctonus ponderosae* Hopk.) on the Kaibab Forest of northern Arizona between 1917 and 1926 is a good example of the potential destructiveness of this species. During this outbreak it was estimated that 300,000,000 board feet of timber, representing 12 percent of the stand, was killed. In the heaviest centers of infestation, on areas 1,000 acres or more in extent, all trees down to those 2 inches in diameter were killed. Large openings in the forest, with remains of fallen snags showing the markings of beetle galleries, attest the fact that similar outbreaks have occurred in the past and may occur from time to time in the future.
>
> Outbreaks of the mountain pine beetle (*Dendroctonus monticolae* Hopk.) in lodgepole pine forests as described by Evenden [1940] are the most devastating

of all in respect to extent and completeness of kill, although this tree species is not so valuable as several other species of pine. In the northern Rocky Mountains an outbreak originating in the Bitterroot Valley in 1922 swept down the Continental Divide and laid waste lodgepole pine forests over thousands of square miles. Estimates placed the total destruction at 7,250 million board feet, with more than 36,000,000 trees having been killed in one national forest alone. [Pl. 5, fig. 2.]

Taking the pine forests of the western States as a whole, recent estimates place the annual mortality associated with bark beetles at 2.8 billion board feet. The magnitude of this yearly figure can best be visualized by comparing it with the 4.4 billion board feet of lumber produced by all western pine sawmills and the 1.4 billion board feet of saw timber killed by forest fires throughout the entire United States in 1936.

DEFOLIATING INSECTS

Defoliating insects have been even more destructive than bark beetles. The larch sawfly (*Lygaeonematus erichsonii* (Hartig)) had practically wiped out larch as a commercial species in the eastern States and Canada by 1910 (Hewitt, 1912) and is now attacking stands west of the prairies. The spruce budworm (*Cacoecia fumiferana* (Clem.)) has repeatedly invaded our forests. (Pl. 9, fig. 2.) An exceptional outbreak in the northeastern States and Canada (Swaine and Craighead, 1924) ravaged the spruce and fir forests for a period of 10 years (from 1910 to 1920), and it has been estimated that in spruce-fir types of Maine, Ontario, Quebec, and New Brunswick from 40 to 70 percent of this timber was destroyed, i. e., the equivalent of more than 25 years' pulpwood supply for current annual American paper requirements (Senate Document 19). Certain species of defoliators, even if they do not kill the timber, cause a cessation or reduction of growth which may increase the rotation period of the stand from 5 to 10 years or more. Such defoliations may be local and confined to a single species of tree or they may spread over enormous areas involving several species. The most recent outbreak of the Pandora moth (*Coloradia pandora* (Blake)) in the ponderosa pine stands of southern Oregon (pl. 7, fig. 2; pl. 9, fig. 1) occurred between 1918 and 1925 and covered approximately 400,000 acres (Patterson, 1929). Growth measurements from plots in this area showed that for a period of 11 years the normal forest growth was reduced an average of 32 percent, or suffered a loss of increment of approximately 100 million board feet. The spruce sawfly (*Diprion polytomum* (Htg.) (pl. 10, fig. 2)) has more recently threatened the spruce forests of the New England States and Canada. In the Gaspé Peninsula in Canada it has already (1940) killed 10,000,000 cords of spruce (Balch, 1941). Late in 1940 it was suddenly checked by a disease which decimated its number throughout its range.

FIRE AND INSECT RELATIONS

Insect outbreaks are occasionally of more importance because of the fire menace they create than because of the value of the timber killed. This condition is described in "A National Plan for American Forestry" (Senate Document 12, 1933), as follows:

> When extensive outbreaks of insects develop in forest types composed chiefly of one species of tree, a high percentage of the stand may be destroyed. These standing dead trees go down in the course of a few years, making an almost impenetrable tangle of logs and tops. Under proper conditions a flash of lightning may set off the mass, resulting in a widespread conflagration almost impossible to fight. Past experience has shown that epidemics of the mountain pine beetle in lodgepole have been followed by fires more often than not. [Pl. 5, fig. 1.]
>
> The old snags of insect-killed trees scattered throughout our mature forests, which average for some areas as many as 10 per acre, stand for many years and greatly increase the cost, difficulty, and danger in fire control. Snag felling is required in many sales of national forest timber, and many private operators have already adopted this regulation. The increased cost of control of fires which have spread from burning snags within fire lines would alone justify insect control even at a high cost.

It should be understood that in making any comparisons between losses from insects and from fire, a certain percentage of this destruction by insects occurs in what are called normal or endemic infestations in timber stands of such low commercial value that an expenditure for control would not be warranted. Such losses are inevitable and are in most cases offset by the annual increment of the stand. Also, as stated in Senate Document 12,

> Forest fires, beside destroying variable amounts of mature timber, kill all the smaller trees and reproduction, and repeated fires leave the land in a totally unproductive condition for generations to come. Forest insect epidemics, on the other hand, destroy only the mature timber and not only leave the regeneration already existing in a better condition for rapid growth but frequently induce copious reproduction.

SCENIC AND PROTECTIVE VALUES

The preceding citation of insect damage in commercial timber is only a part of the picture. To quote again from Senate Document 12,

> The importance of the forest cover in national parks, game preserves, and recreational areas cannot be estimated in monetary values. Here aesthetic and protective values far outweigh those of commercial timber. One of the greatest attractions in these areas is a green forest cover on which much of the natural beauty of the parks is dependent. The trees also give protection to the birds and animals.

Insect depredations which mar the scenic value or destroy the protective values of the forest cover in these parks and recreational

areas have in late years become of even greater moment than those involving only commercial timber.

DEVELOPMENT OF BARK BEETLE CONTROL

As our reserve supplies of timber became depleted from utilization, fire, and insects, and recreational activities continued to spread into more and more remote areas, private timberland owners and Federal administrators of timbered areas became more conscious of the need of any action that would delay part of this depletion. A short sketch of this work is of interest.

The first control project, as mentioned previously, was initiated on the Black Hills National Forest in South Dakota in 1906, when $2,700 was expended in an effort to check an epidemic of the Black Hills beetle. Since then many projects have been carried out, some of them covering areas of more than 1,000,000 acres. Up to the present time (fiscal year 1941) approximately $8,000,000 has been expended in the control of bark beetle infestations, mainly in reserves of timber which are being held until conditions warrant logging and marketing of the lumber.

The annual expenditures from 1906 to 1921 were small—rarely over $20,000 and usually much less. Since 1922, with the fuller appreciation of the importance of insect losses, increasing amounts have been spent each year for the protection of valuable timber stands. From regular appropriations the Forest Service has spent $100,000 to nearly $200,000 annually, the Park Service from $40,000 to $50,000, and the Office of Indian Affairs from $10,000 to $20,000.

During late years it has been possible to meet the needs for forest insect control more adequately by means of increased funds available to land-managing agencies through emergency legislation and Civilian Conservation Corps labor. During the fiscal year 1937, and for several years since, nearly a million dollars or its equivalent in manpower was utilized in insect control work on Federal lands.

As control work proceeded, year by year the need for competent technical advice became more and more apparent. Trained men were needed to appraise the character of the insect infestations, to make recommendations to the timberland owners or administrators, and to direct technical features of control. This resulted in the development, within the Bureau of Entomology, of a service for these purposes. The objectives of such a service were set forth in a memorandum by the Secretary of Agriculture dated February 16, 1920, covering the responsibilities of the Bureau of Entomology and the Forest Service. In time this understanding has been interpreted as applying to all other Federal agencies managing timberlands. Briefly, the instructions stated that the Bureau of Entomology shall be responsible for

surveys, for making specific recommendations on the need of control work, and, when necessary, for the technical direction of control. This service was extended to private owners as well. A fine spirit of cooperation between the several national agencies managing timberlands, namely, the Forest Service, the National Park Service, the Office of Indian Affairs, and the Bureau of Entomology (lately the Bureau of Entomology and Plant Quarantine) has facilitated this plan.

Gradually these surveys have been developed to cover many of the more important timber types in the western States although the job is still far beyond the appropriations available. During 1940 the Bureau of Entomology and Plant Quarantine covered in these surveys over 23 million acres in all types of forests. Much of the country was covered by general reconnaissance surveys, while certain areas required intensive detailed estimates. These results were reported to the agencies administering these timberlands and in many cases recommendations for control were suggested and carried out.

As this control program increased, it stimulated new ideas and technique and provided large-scale tests for these developments.

To quote Craighead et al. (1931),

> Control methods necessarily must be based upon information regarding the seasonal history and habits of the insects, and also, until thoroughly tried out in practice, upon certain conceptions and theories. Each species of bark beetle presents its own special problem, and even the same species may present problems which differ in different regions.

Control of bark beetles is admittedly expensive. (Pl. 3; pl. 6; pl. 7, fig. 1.) According to Craighead (1938),

> It involves the spotting of infested trees in the forest, followed by felling, barking, and often burning of the bark to destroy the beetles and thus prevent new broods from emerging from infested trees and attacking nearby green trees. Usually the largest trees in the forest are attacked and the labor required for spotting, felling, barking, and burning costs from $2 to $20 per tree, depending on its size, accessibility, type of timber, and other factors. Such costs are a limiting factor in the application of control, as frequently the expenditures run too high to make control economically feasible. In recent years several new methods have greatly reduced these costs.

The so-called solar-heat method was tested out on a large scale in lodgepole areas in Oregon by Patterson (1930) and found to be successful under certain conditions. It consists of simply felling the tree and exposing the trunk to full sunlight, later turning the log to expose the underside. The heat generated under the bark by the direct rays of the sun is sufficient to kill the brood. In California the thick bark of yellow pine and sugar pine is first peeled and then spread out in the sun.

About 1926 a method was devised for burning the infested bark from standing lodgepole pines. It was tested on several large projects in

southern Idaho and proved to be effective and economical. (Arrivee, 1930.)

The possibility of injecting chemicals into the sap stream of the tree and thus preventing the development of the bark beetle broods and doing away with the costly operations of felling and barking or burning the tree for the control of bark beetles has been experimentally tested during the last few years. There appears to be some promise in this field, both from control and salvage standpoints, but it has a practical difficulty in that treatment is necessary shortly after the beetles attack, i. e., before the blue stains in the sapwood cut off conduction. (Craighead and St. George, 1938.)

One of the disadvantages of bark beetle control has been the loss of the lumber from the trees that are treated. Studies by Keen (1931) of the salvage possibilities of beetle-killed timber have led to some practical methods of treating this problem. He says:

> A great deal of attention has been devoted by our entomologists in the last few years to the use of so-called salvage methods of control, and the Forest Service and private timberland owners have cooperated heartily. In the ponderosa pine types of eastern Oregon and northeastern California when the terrain permits caterpillar logging, prompt spotting and salvage of these trees is feasible. [Pl. 3, fig. 1.]

It has long been desirable to have a method of treating infested trees through the summer period, one that would be quick in action and avoid the use of fire, which is so dangerous at that time of year. After considerable experimentation several penetrating sprays were developed which, when applied to the trees, promise to meet this need effectively. The most satisfactory chemical is orthodichlorobenzene carried in light fuel oil. This method is particularly well suited to the control of mountain pine beetle broods under the thin bark of lodgepole and white pines in the Rocky Mountain regions. (Salman, 1938.)

The lethal effect of low winter temperatures has been taken advantage of to call off control work on projects already under way when temperatures dropped to a sufficiently low level to destroy the broods. (Miller, 1931; Keen, 1937.)

RESULTS OF BARK BEETLE CONTROL

A review of the control work against bark beetles in our forests and an appraisal of its values were summarized by Craighead, Miller, Keen, and Evenden in 1931. It should be explained here that control work is carried out only against a small percentage of the outbreaks. In inaccessible timber, where new trees will replace those destroyed before the area is logged or where commercial values do not warrant large direct expenditures, control is seldom undertaken

unless recreational or scenic values are at stake or unless outbreaks in remote areas threaten commercially valuable stands. In general only where utilization is anticipated in the next 10 to 25 years is control economically feasible.

The results might be said to be more or less in direct proportion to the aggressiveness of the beetle. The Black Hills beetle, which appears to be one of the most destructive of all species of *Dendroctonus*, seems to build up into aggressive outbreaks rather suddenly and, after locally killing extensive areas of timber, disappears quite as rapidly. Control efforts against this species have been uniformly successful if thoroughly applied. The southern pine beetle is equally as aggressive. Its outbreaks have been definitely shown to be tied in with deficiencies in rainfall extending over a period of several months. Direct control is, however, more difficult here because of the short duration of many outbreaks. The mountain pine beetle in lodgepole pine behaves much like the Black Hills beetle and has wiped out tremendous volumes of mature timber. Here, again, control work has been successful when persistently applied. On the other hand, this beetle's activities in the white pine type of the northern Rocky Mountain region and the sugar pine type of California are quite different. The western pine beetle in the ponderosa pine type of Oregon and California may be classed as the least aggressive of all these species, in that it seems to show a definite predilection for certain weakened trees and its activities appear to run in cycles associated with definitely unfavorable weather. This correlation has been frequently noted and recently developed by Keen in a study of tree growth, precipitation, and bark beetle activities. The climatic influences that dominate the growth pattern undoubtedly have a direct effect on the insects. (Keen, 1937.)

CONTROL OF FOREST DEFOLIATORS

Even greater efforts have been expended against some defoliating insects. The gypsy moth is a European insect which reached eastern Massachusetts in 1869. Some 20 years later it had become well-established and attracted popular attention because of its widespread defoliation of hardwood trees. The State of Massachusetts undertook control work, which continued until about 1899. Then there was a period when no work was done and the insect increased rapidly. In 1905 the Federal Government stepped into the picture in an effort to prevent its spread to other States to the south and west. Since that time more money has been spent on the control of the gypsy moth than has been spent on all other forest insects combined. In 1934, total expenditures, State and Federal, to date were approximately $40,000,000. Since then, through C. C. C. and relief funds, some $20,-

000,000 additional has been spent. This is obviously out of all proportion to the immediate damage in the infested area, notwithstanding the fact that in the early days of the gypsy moth, before it had been acclimated to behavior more or less like that of a native insect, it did cause tremendous destruction of oaks and associated pines in eastern Massachusetts. It was the danger that it might spread south and west throughout the eastern hardwood regions that warranted large-scale, continued effort.

Aside from the value of local suppression and prevention of spread of the gypsy moth, this program developed many features of inestimable value in the control of forest, shade, and fruit-tree insects.

Spraying of woodland areas has developed into something of a "big business" with a scientific background. Modern high-pressure spraying machines and other equipment have been evolved to meet the necessity. This technique now has wide application in all parts of the country. The adaptability of the autogiro (pl. 10, fig. 1) for applying arsenicals over forested areas has been demonstrated, and this type of equipment bids fair in time to supplant completely the use of ground machinery. It may lower the cost of the application of insecticides to such a figure that it will be economical to protect forest lands on the basis of the value of the threatened stand rather than on the additional threat of spread to, and destruction of, forest in other areas. Lead arsenate, one of the most widely used arsenicals, was developed commercially.

For many years an extensive program of parasite introduction was carried on in an effort to establish the principal insect enemies of the gypsy moth in this country. Most of the important foreign parasites are now firmly established here and several of them have spread throughout the gypsy moth infested region. This was the first large-scale undertaking of this kind, and the knowledge gained has served as a basis for studying parasites of a large number of injurious insects.

Many other destructive outbreaks of defoliators have occurred from time to time in our forests but most of these developed unobserved to such magnitude and declined with such abruptness that it has been impossible to organize a control campaign. Suppression work on many smaller direct-control projects in scenic and recreational areas in our national parks and national forests have been carried out during this period and will undoubtedly be conducted more frequently in the future as the use of these recreational areas increases and costs of application are reduced.

CONTROL OF VECTORS OF THE DUTCH ELM DISEASE

The Dutch elm disease can logically be referred to here inasmuch as its spread is entirely due to insect vectors, chiefly the small bark

beetle *Scolytus multistriatus* (Marsham) (pl. 11), introduced from Europe, and a native bark beetle, *Hylurgopinus rufipes* (Eich.). Without these associates the disease could do no damage. In this case, control emphasis has been placed on the disease, although actually the case is a close parallel to our bark beetle problems, where several species of *Ceratostomella*, or blue stains, are introduced by *Dendroctonus* into the stems of pine and spruce to bring about their destruction. More and more the control of this disease is becoming a problem in the control of the vectors.

Scolytus was introduced from Europe many years ago and is widely distributed. When the disease first appeared in 1930 a survey showed that it was well established in New Jersey and that a few outlying infections existed. An eradication program was undertaken in 1935. At the present time over $25,000,000 has been spent.

As in the case of the gypsy moth control campaign, this large intensive campaign has perfected methods, particularly in scouting and chemical control, suitable for application to future similar emergencies that may arise.

RÉSUMÉ ON DIRECT CONTROL

Thus during a period of some 40 years, beginning at a time when many of the most destructive of our forest pests were still new to science, the threat of insects to our reserve timber stands, their capacity in marring scenic and recreational values, their destruction of second-growth forests, and their importance as a fire menace have become widely appreciated, and highly specialized organizations for the prevention or control of these losses have been developed.

During this period more than $100,000,000 has been spent and in recent years $5,000,000 to $10,000,000 annually has been utilized in protective measures. The annual expenditures by the United States Forest Service for fire protection is approximately $15,000,000.

PROTECTION THROUGH MANAGEMENT

The foregoing discussion presents a broad picture of insect activities in our forests and of man's efforts to counteract their destructive tendencies where the timber stands are of sufficient value to warrant direct expenditures for control. Such effort has been based on the theory that the necessary expenditures are justified because of the greater value of the green timber saved by this action or because of the recreational values involved.

Gradually, while this was going on, entomologists and foresters were thinking of the future, toward a time when methods for growing timber crops so as to avoid insect losses could be substituted for

artificial control. Definite suggestions along these lines were expressed very early by Hopkins (1909a):

> The desired control or prevention of loss can often be brought about by the adoption or adjustment of those requisite details in forest management and in lumbering and manufacturing operations, storing, transportation, and utilization of the products which at the least expenditure will cause the necessary reduction of the injurious insects and establish unfavorable conditions for their future multiplication or continuance of destructive work.

Curiously enough the principles for growing or handling forests to avoid insect attack are best learned from the study of the insects themselves. As mentioned previously, insect losses are only serious when they interfere with man's need. For generations certain types of forests have been destroyed by insects and rebuilt through growth, and this process is still going on unnoticed and of little concern to man in the more remote areas. Nature also uses insects for the removal of certain shade-intolerant or temporary species of trees from the forest, thus hastening the arrival of the climax type.

Many excellent examples of such activities have been observed and recorded. The first might be illustrated by the activities of the Black Hills beetle on the Kaibab Plateau, an area relatively undisturbed by man. To quote Craighead (1924):

> This beetle has been present in this forest, killing enormous quantities of timber, probably since the forest has been in existence, although absolute records can only be dated back 400 years. The activities of these beetles have been almost continuous with intermittent periods of greater epidemicity * * * Generally speaking, the forest consists of a densely stocked immature stand. Stands of old mature timber are very limited in extent * * * These beetles have in reality been putting into effect a form of management—cutting by a group system the annual increment of the forest for hundreds of years in the past and providing at the same time good conditions for reproduction. But little study is needed to convince one that this system has been highly successful from the standpoint of producing rapid growth and fully stocked stands.

An illustration of the action of insects in effecting natural forest succession is provided by the 1910–20 spruce budworm outbreak in eastern Canada and the northeastern part of the United States, as described by Swaine and Craighead (1924) and by Graham and Orr (1940). This outbreak was one phase of a slow process of natural forest succession over extensive areas. The temporary types, composed largely of aspen and birch, were gradually replaced by mixtures of balsam fir, spruce, and red and white pine. The forest tent caterpillar (*Malacosoma disstria* Hbn.) probably aided in this conversion by killing some of the aspen and birch and thus releasing the coniferous understory. By the time the fir and spruce reached maturity they formed a considerable part of the upper crown canopy and thus made conditions favorable for an outbreak of the spruce budworm. The budworm killed most of the mature fir and some of

the spruce. The eastern spruce beetle was also a factor in killing overmature spruce. Insects were thus important in the production of the extensive stands of white pine of early logging days—giant trees 300 or more years of age overtopping a spruce-fir-hardwood understory.

The application of entomological knowledge to forest management must go hand in hand with practical developments in forest utilization. Many schemes have been suggested for handling timber stands, particularly second growth, to avoid some specific insect damage. Many of these may eventually be applied but most of them are still impractical because of economic considerations.

FROM DIRECT BARK BEETLE CONTROL TO SELECTIVE LOGGING OF SUSCEPTIBLE TREES

Probably the most persistent effort in the application of entomological knowledge to the management of timber stands has been expended for the prevention of bark beetle losses in the ponderosa pine type of California and Oregon.

During the period of increasing control work, while we were utilizing our overmature reserves of timber, many of the disadvantages of direct control became apparent, particularly the costliness and the variability of the results and the fact that much of the timber treated could seldom be utilized but had to be left in the woods to decay.

That the western pine beetle (pl. 1) should have been one of the first insects for which definite suggestions were made for substituting management for direct control is easily understood. Extensive stands of increasingly valuable timber were at stake, losses in the best-quality timber were increasing, biological studies and control efforts were pushed more energetically than for any other beetle, and, most important, it was realized early in the study of this species that it showed a decided preference for trees with certain recognizable characteristics and that advantage might be taken of this preference in marking timber sales.

Hopkins (1909b) notes the preference of this beetle for "larger, best matured trees."

Pearce (1920) pointed out that "beetle activities in our pine forests not only represent a serious economic loss but must be taken into consideration in planning for sustained yield."

Craighead (1925a) expressed this idea as follows:

> Generally speaking, the western pine beetle appears to prefer overmature, slow-growing, decadent trees, particularly those on poorer sites * * * There is no doubt, however, that successful management of the western yellow pine is just as intimately tied up with this beetle problem as it is with fire or with the silvical characteristics of the tree and that the beetles' ability to increase in

numbers is conditioned by physiological changes in the trees brought about by deficiency in rainfall or opening of the stand which allows greater desiccation.

Person (1928) was the first to give this predilection of the beetle for certain trees a definite terminology, using "tree susceptibility" and "beetle selectivity." His work showed that

* * * tree selection, as used in this paper, is not intended to mean a conscious selection of certain trees by the insects, but rather that trees having certain characteristics are more apt to be killed by the western pine beetle than trees which do not have them.

The preference of the western pine beetle for the slow-growing trees varies with the area and the status of the infestation, being more marked under endemic or increasing conditions than under decreasing epidemic conditions.

The slow-growing trees, which are of least value for producing wood, are the trees most likely to be killed by the western pine beetle. If these trees can be taken out in the earliest cutting of timber the condition of cut-over areas will be materially improved from the standpoint of insect damage and of subsequent growth.

In a later paper (1931) Person states:

Any increase in our knowledge of how the western pine beetle selects the trees which it kills will make it possible to reduce this loss by leaving on our cut-over areas only such trees as will have the best chance of surviving until the next cut.

A greater knowledge of tree attractiveness and stand susceptibility will make it possible to determine the probability of insect loss when the logging plan is first drawn up, before the insect loss occurs, thus obviating the necessity of later changes, which are usually costly.

Dunning (1928), in presenting a tree classification for western yellow pine, recognized the importance of bark beetles as a mortality factor. To quote: "The greatest single cause of mortality was bark beetles (*Dendroctonus*) which killed 61, or 35 percent, of the 172 trees and accounted for 50 percent of the basal-area loss." He also comments on the possibility of using in management, the selectivity shown by these beetles, stating that "The elimination of susceptible trees in cutting would doubtless lessen endemic insect damage, the most important cause of loss on cut-over areas."

In presenting an appraisal of control, Craighead, Miller, Keen, and Evenden (1931) point out that the results of control work against the western pine beetle have "not been spectacular or outstanding * * * and the benefits only temporary. * * * Such (control) work may be combined with selective logging to remove susceptible trees and produce better growth conditions in order to give permanent protection for long periods."

Further developments with this idea were reported in 1933 (Senate Document 12) following actual experimental tests in removing beetle-susceptible trees (fig. 1):

Much progress has been made in recent years toward establishing sustained yield on both Federal and private timberlands in the ponderosa pine type of California and Oregon. The management of these stands is based on an initial

partial cutting, leaving a sufficient reserve of timber for future growth, so as to enable a second cutting in from 30 to 40 years. Bark beetle losses in these stands reserved for future growth have in certain areas not only offset all increment, but have reduced the original forest capital from 1 to 15 percent. Recent experiments have indicated the possibility of avoiding this loss by removing insect-susceptible trees in the initial cutting. These susceptible trees are those of slower growths which can be detected at the time of marking the timber for sale. Recent sales have been marked on this plan.



FIGURE 1.—Touched-up photographs to illustrate types of ponderosa pine susceptible to bark beetle attack. Lowered vigor and resistance and greater susceptibility indicated by higher numbers. (Salmon and Bongberg.)

Keen (1936) was the first definitely to classify ponderosa pine on the basis of susceptibility to bark beetle attacks. He proposed a classification based on age and vigor (crown size, shape, and density) that has served very well for this purpose and has been widely adopted by foresters for other purposes as well (fig. 2). He says:

Once the type of tree most likely to be killed can be recognized with a fair degree of certainty, it is possible to make partial cuttings of beetle-susceptible trees, either for the purpose of salvaging valuable high-risk trees before they are damaged by beetle attack or for the silvicultural objective of reducing mortality and increasing net growth.

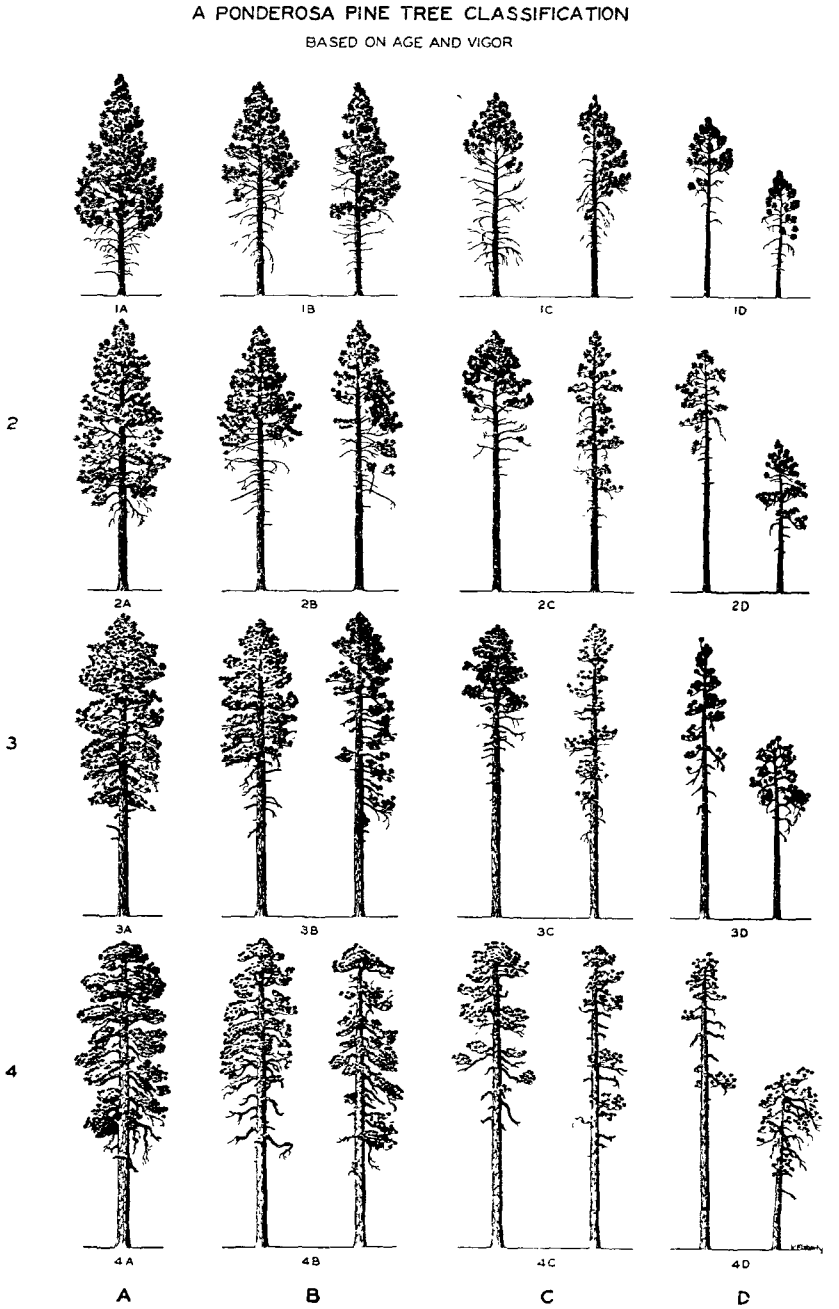


FIGURE 2.—Keen's tree classification based on age and vigor.

These studies have revealed that the risk of being killed by western pine beetles is distinctly greater for trees of certain types than it is for other trees in the same stand. In general, the trees more susceptible to attack are the weaker, less vigorous individuals and, to a certain degree, those more advanced in age. The problem, therefore, is one of recognizing the combination of characters which indicates susceptibility.

Silvicultural management of our ponderosa pine forests should eventually lead to the solution of the present pine beetle problems. Although forest management may not eliminate all future bark beetle troubles, it is at least a step in the right direction of improving the chances of ponderosa pine stands to escape such injury.

The practicability of Keen's scheme was quickly recognized, and actual marking of timber sales by this classification was carried out in Oregon and Washington and adaptations of the system were used by foresters in the Southwest and in the Rocky Mountain regions. The results were good and led to further study and refinement of the characteristics of "bug trees."

About this time thought along these lines had crystallized sufficiently to demand further experimental plots for testing the possibilities of marking beetle-susceptible trees. In 1936, on the Blacks Mountain experimental area, the California Forest Experiment Station set aside certain areas for use of the Berkeley laboratory of the Bureau of Entomology and Plant Quarantine, and Bongberg and Salman marked the "bug trees" on the basis of their ideas of the characteristics that indicate susceptibility. After 4 years the results of this work have been highly satisfactory and are being applied by private interests and the United States Forest Service in Oregon and California. Salman and Bongberg (1941) have shown that on these experimental areas they were able to mark and remove before attack 85 percent of the trees that would have been destroyed by bark beetles from comparison with the losses on adjacent areas.

Thus after many years of direct-control efforts against the western pine bettle and the testing of several methods for marking and cutting of ponderosa pine on Federal and private lands in an effort to obtain sustained yield, we are now anticipating nature's ruthless but effective method—selection by climate and beetles. For many years this selection system has been going on before our eyes but only recently have we seen it—no doubt, we still see only a part of it. It is still too early to predict the success of this method, aptly phrased "beating the bettle to it." Theoretically it looks good. If we remove the susceptible trees before the beetle broods develop in them, it seems reasonable to believe that beetles cannot increase in numbers and become aggressive to the point of killing nonsusceptible trees. In practice, success will depend on several considerations. Logging methods and terrain, as well as the lumber demand, will

govern the size of the cut. The "beetle system" will demand low-volume removals at frequent intervals in most stands. Can we modify our usual cutting practices so as to remove more frequently the susceptible crop of trees? Under favorable weather and beetle conditions, as have recently prevailed, it seems possible to do this with a light cut every 5 years or so. Under adverse conditions, such as prevailed 10 to 15 years ago, it would have been necessary to remove 25 to 50 percent of many stands in a few years.

This discussion pertains to overmature and usually understocked stands. It does not consider the conditions that will prevail once these stands have been removed and abundant reproduction occupies the ground. Obviously the competition in these younger stands will offer conditions favorable to group attacks by the bark engravers (*Ips*) and the mountain pine beetle, even if the western pine beetle is not abundant, and judicious thinnings will be required to prevent the excessive opening of the stands by large group attacks, thus bringing about local understockings or conversion of type to less desirable species (Craighead, 1936; Eaton, 1941). Pearson and Wadsworth (1941) recognized this need in their experimental work with ponderosa pine on the Colorado Plateau and show preliminary favorable results from thinnings by poisoning and pruning of crop trees.

This marking and removal of low-vigor trees has been recommended and applied only to the east-side ponderosa types of California and Oregon. In the west-side types of more vigorous growth, beetle outbreaks are less important. They occur in definite short periods and die out as suddenly as they develop.

THEORIES OF BARK BEETLE SUSCEPTIBILITY

As indicated in the preceding discussion, the susceptibility of certain trees to bark beetle attack has been recognized for a number of years. Various explanations have been advanced for this susceptibility. Some of these are published and others are developed in reports and correspondence in the files of the Division of Forest Insect Investigations. A thorough understanding of what makes these trees susceptible to bark beetle attack would aid materially in the application of preventive measures.

Observations in the field have shown that mortality in the ponderosa pine type varies tremendously from periods of low (endemic) loss to periods of excessive (epidemic) loss; that during certain periods many trees die with few or no insects present; that others may be infested by wood borers only; and still others are attacked by bark beetles which introduce blue-staining fungi into the sapwood, thus cutting off the transpiration stream between the roots and the crown.

This same picture applies more or less to all bark beetle outbreaks in all parts of the United States.

It is obvious that any satisfactory explanation for the susceptibility of trees to bark beetle attack must also explain all the observed facts during the ups and downs of these outbreaks. It is the writer's opinion that the condition is induced primarily by lack of moisture, chiefly from drought but also from excessive competition within the stand. It is probable that in the case of ponderosa pine, as with other trees, the roots are first affected.[2] Then, in turn, the foliage thins out to compensate for a reduced root system. The topmost branches often die. Certain insects that kill the twigs (such as scale insects and the birdseye pine midge, *Retinodiplosis* sp., pl. 8, fig. 1) may bring about additional defoliation. This all results in the manufacture of less food and consequently narrower rings, which in turn may reduce the volume of conduction, all of which contributes to lowered vigor to the point where many trees cannot recover.

Thus it could be that under adverse conditions many trees die from the effects of the physical environment without insect attack; others are attacked by borers which in themselves are not very important—at least no sound physiological explanation of the effects of their attack has been offered—but are only symptoms of a deeper malady. These "predisposing insects" of Graham (1939, p. 226), Keen and Salman (1941), and West (1941), with their special senses can recognize this moribund condition before we can, and act accordingly. Such insects appear to be the principal factor only because they are immediately associated with visual symptoms of death. Others of these trees in slightly better condition do not fade (die) until conduction is completely and quickly cut off by blue-staining fungi introduced into the sapwood by bark beetles (Nelson and Beal, 1929). This theory implies that many trees go out of the stand from the effects of an adverse physical environment and may serve as hosts to numbers of borers and other insects, whereas other trees less seriously affected by drought serve as suitable host material for breeding up large populations of bark beetles. It is conceivable that the lowered water content and possibly higher oxygen content of the wood associated with drought (Nelson, 1934; Caird, 1935) are necessary for development of the blue stains, which, in turn, condition the tree for optimum development of bark beetle broods (Leach, Orr, and Christensen, 1934).

From this it should by no means be inferred that these bark beetles cannot by their attack kill healthy trees. The aggressiveness

[2] Secrest, MacAloney, and Lorenz (1941) have shown that the foliage of drought-affected hemlocks may remain green several years even when the tree has a dead root system (apparently sustained by stored food in the trunk and moisture received through the dead roots).

of the beetles depends on their abundance, as they kill by gregarious attack, introducing into the active sapwood fungi that cut off conduction. When they become abundant their gregarious attack will kill trees that are apparently in full vigor and which show no characteristics of susceptible trees, but as the condition of the borderline trees improves with increased moisture more bettles are required to kill a tree, poorer broods develop, and the insects decrease in abundance and consequently are of decreasing importance.

This theory appears to be supported by evidence collected from other insect outbreaks and drought periods in the more humid parts of the United States. That such comparisons are not too farfetched is supported by the following recent statement by Pearson and Wadsworth (1941):

> Notwithstanding local variations in size and growth rate, ponderosa pine behaves in much the same way wherever it is found. There is also more in common between different species in widely separated regions than foresters generally realize. The influence of light and shade and of root competition, though differing in degree, is fundamentally the same whether one is dealing with ponderosa pine in Arizona, with pines in the South, or the Lake States, or with Douglas-fir in the Pacific Northwest.

The southern pines (shortleaf, loblolly, and longleaf) have from time to time been subjected to sharp local droughts which have killed large volumes of timber. Outstanding among these was the summer drought of 1924 in Texas and Louisiana, when a deficiency in precipitation of some 15 inches, occurring from June to January, resulted in the destruction of over 100,000,000 board feet of timber. Although *Ips* were prevalent in the dying trees, much of the timber was very lightly infested. (St. George, 1925.)

A few years later Cary (1932) reports a similar drought in Florida and Georgia extending through 7 months, which destroyed nearly as much pine timber. The southern pine beetle was notably absent in these occurrences, as outbreaks are rare in longleaf and slash pines, although this insect does attack these species. Personal experience in both these cases was very convincing as to the greater effect of drought and the secondary importance of the associated insects.

Blackman (1924) showed that the attack of the hickory bark beetle was dependent on a moisture deficiency and that the attacking insects were destroyed when normal rainfall was resumed. Craighead (1925b) analyzed a series of outbreaks of the southern pine beetle in shortleaf pine and found that the same conditions held. Subsequent observations have upheld this evidence and have permitted issuance of warnings when precipitation has dropped below normal.

For some time it had been recognized that a more systematic study of the interrelationship of tree susceptibility and climate was necessary in the ponderosa pine type. Any direct connection between timber losses and deficiency of precipitation has been much more difficult to establish in the ponderosa pine type because of the lack of adequate records in the timber areas and the apparent adjustment of this pine to the rainless summers of the region. Three years ago at our Berkeley laboratory R. C. Hall initiated such a field study, establishing locations in several timber types and on several timber sites, amply supplied with instruments to measure various environmental factors. In these areas insect records and timber losses are available over a long period of years. Already, after 3 years of observation, very striking information (unpublished reports) has been obtained indicating a close tie-up between climate, past timber losses, and beetle activities, even definite variations within the different sites of the ponderosa type.

MANAGEMENT FOR INSECT CONTROL IN SECOND-GROWTH STANDS

In the eastern States, particularly in some private forests, silvicultural systems primarily designed to circumvent insect damage have been applied in pine and hardwood stands. Such insects as the gypsy moth, the white pine weevil, the locust borer, the turpentine borer, and the bronze birch borer have each been the dominant factor in shaping management plans of the forest types in which they are active.

Fiske (1913) was probably the first in this country to realize the possibility of controlling the gypsy moth through forest management. He suggests taking advantage of the preference shown by the larvae for certain species of trees and removing these, especially oak, from the stands.

This possibility of control through adjustment of food plants stimulated extensive studies by the Bureau of Entomology which were published by Mosher (1915). Mosher classified the plants in the regions into the following four groups: (1) Species highly favored by all stages of gypsy moth larvae; (2) species that are favored food for the gypsy moth after the early larval stages; (3) species that are not particularly favored but upon which a small proportion of the gypsy moth larvae may develop; and (4) species that are unfavored food.

The gypsy moth develops normally and becomes destructive only on plants of group 1.

From the germ of Fiske's suggestion and the definite classification proposed by Mosher, the possibility of silvicultural control gradually gained recognition and resulted in a cooperative study between the

Forest Service and the Bureau of Entomology to obtain more specific data and to test out theories by means of experimental plots. This study was assigned (Clement, 1917) to Clement and Munro, who reported on their work in Bulletin 484 of the United States Department of Agriculture. They indicated certain possibilities and certain limitations, chiefly economic, in the application of management to gypsy moth control. The proposals were a little ahead of the times and no general application resulted.

A more recent study of this problem in central Massachusetts through cooperative efforts of the Bureau of Entomology and Plant Quarantine, the Harvard Forest, and the Northeastern Forest Experiment Station developed more specific information. First, Baker and Cline (1936) showed that no serious defoliation occurred unless more than 50 percent of the stand was composed of species of group 1. Continued study led to definite recommendations by Behre, Cline, and Baker (1936) and indicated that there are very far-reaching possibilities for applying the principles of forest management to the control of the gypsy moth in the New England States, because of the favorable conditions which existed, namely, (1) the composition of much of the forest with regard to the distribution of favored and unfavored food plants was suitable to work with in thinning practices; (2) there were large areas of second-growth hardwoods, many of them with understories of conifers, which needed release; (3) the Federal and State agencies were then spending considerable sums on less permanent methods of control, such as spraying and creosoting egg masses. This money would do more permanent good if diverted to forest improvement; and (4) considerable manpower was available (at the time of writing) through C. C. C. camps and relief organizations.

The ice is now well broken and it is likely that silvicultural measures will be given more and more emphasis and the present control program will change from one of temporary practices, such as spraying and creosoting, to one involving the permanent improvement of forest stands. It is reasonable to believe that with such measures a large part of the present infested area can be made relatively immune to the gypsy moth and a considerable reduction in expenditures for control can be effected.

These writers (Behre, Cline, and Baker, 1936) showed how the cutting practices of the past 30 years and frequent fires led to the increase of secondary types which are primarily composed of species of group 1, and thus brought about more favorable conditions for the gypsy moth. To quote:

> Thus it becomes evident that the forest types which present most favorable conditions for gypsy moth attack are the direct result of a transient agriculture and the destructive lumbering practices of the past.

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Definite recommendations are made for treating the predominant stands of the regions, namely, coniferous plantations, coniferous understories, mixed conifers and hardwoods, and mixed hardwoods of commercial importance. The writers conclude:

> Consideration of the history of the gypsy moth and of existing forest conditions in New England leads to the conclusion that, in spite of all control effort to date, epidemic outbreaks with serious defoliation may continue to occur within the infested area.
>
> Increasing the proportion of woodland in which conditions are unfavorable for the development of the insect should lessen the need for artificial control and reduce the frequency and severity of outbreaks. * * * With few exceptions, elimination or reduction of highly favored food species will conform to desirable silvicultural practices. Silvicultural control, therefore, has the added advantage of serving the objectives of forest improvement.

An introduced insect may thus prove to be the dominant factor in shaping plans for the management of large areas of New England forest land, provided our present appraisal of its economic importance has not been too pessimistic.

A dominant factor in shaping cultural practices for white pine in the Northeast has been the white pine weevil. As farm lands were abandoned a generation or more ago, they seeded in to stands of white pine. In addition many acres were planted. Gradually it dawned on the landowners and foresters that many apparently vigorous stands were worthless "cabbage pines" as the result of repeated attacks of the white pine weevil. The many desirable characteristics of this tree, particularly its rapid growth and high-quality wood, led to repeated investigations of the weevil problem, culminating in recommendations by the Bureau of Entomology and Plant Quarantine, the New York State College of Forestry, and Harvard Forest for growing mixed stands of hardwoods and pine to avoid weevil damage (MacAloney, 1932) and for the reclamation of merchandise boles from badly weeviled stands. (Cline and MacAloney, 1931, 1933, 1935.)

Continued experimental work on the Harvard Forest tracts with pines planted among hardwood seedlings was recently verbally reported to the writer by A. C. Cline, director of Harvest Forest, indicating simplified measures of growing these mixtures to avoid weevil damage (pl. 8, fig. 2). It is obvious that white pines of value cannot be grown commercially in the Northeast unless these methods or subsequent modifications of them are utilized.

Dying white and yellow birch in overmatured stands or following logging operations or severe droughts have invariably been found infested with the bronzed birch borer (*Agrilus anxius* Gory) in the Northeast and in the Lake States. Studies of this insect (Hall, 1933) have led to the conclusion that "changes in the physical factors of the

environment brought about through the medium of logging are often such that trees left will succumb without the attack of either insects or fungi, and the borer plays only the role of a secondary factor in hastening post-logging decadence."

Thus a study of this insect has led to a better understanding of the silvical characteristics of these trees and the need of modification in cutting practices.

The turpentine borer, *Buprestis apricans* (Herbst) (pl. 12), has been a contributing factor in shaping plans for the management of the turpentine groves of the South. This borer attacks the faces of turpentined trees, riddling the entire bases of the trees with its mines and so weakening them as to cause extensive wind throw. It was found that only "dry-faced" or fire-scorched faces from which the protective coating of resin had been removed were attacked. This emphasized the value of conservative practices, such as narrow chipping and fire protection—practices which were advocated for obtaining better yields of gum (Beal, 1932).

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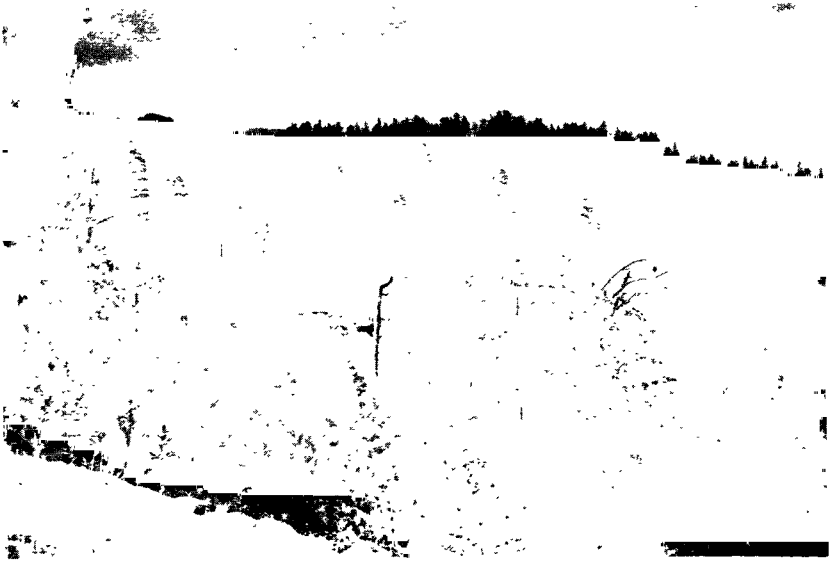
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THE WESTERN PINE BEETLE (DENDROCTONUS BREVICOMIS)

1, Adult beetle. About 8 times natural size. 2, larvae *in pupal* cells in bark, 3, pitch tubes on surface of bark at *entrance to* egg gallery. Dead beetle encased in the pitch Exact size; 4, winding egg galleries *on inner* surface of ponderosa pine bark; 5, lower trunk of *ponderosa* pine tree barked to show egg galleries.



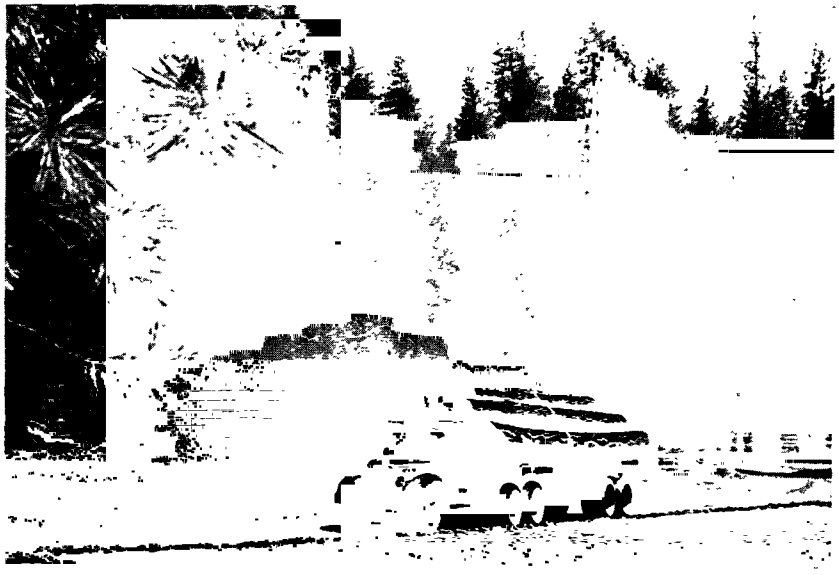
1. INFESTATION OF THE MOUNTAIN PINE BEETLE IN A VIRGIN STAND OF SUGAR PINE.

Yosemite National Park, Calif. August 1932. The light-colored trees are recent attacks and have been faded for only a short time.



2. PONDEROSA PINE TIMBER IN MODOC NATIONAL FOREST, CALIF., KILLED BY THE WESTERN PINE BEETLE.

Eastside pine type. September 1932.



1. SALVAGING BEETLE-KILLED PONDEROSA PINE TIMBER ON THE SHASTA NATIONAL FOREST CALIF.

The infested logs are being trucked to the mill over forest roads July 1939



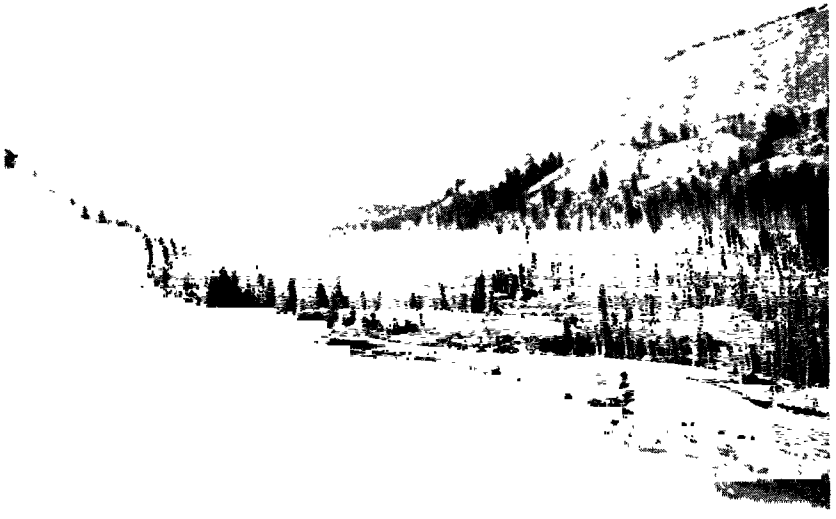
2. BURNING THE INFESTED BARK ALONG THE BOLE OF A LARGE PONDEROSA PINE TREE

Stanislaus National Forest, Calif May 1935.

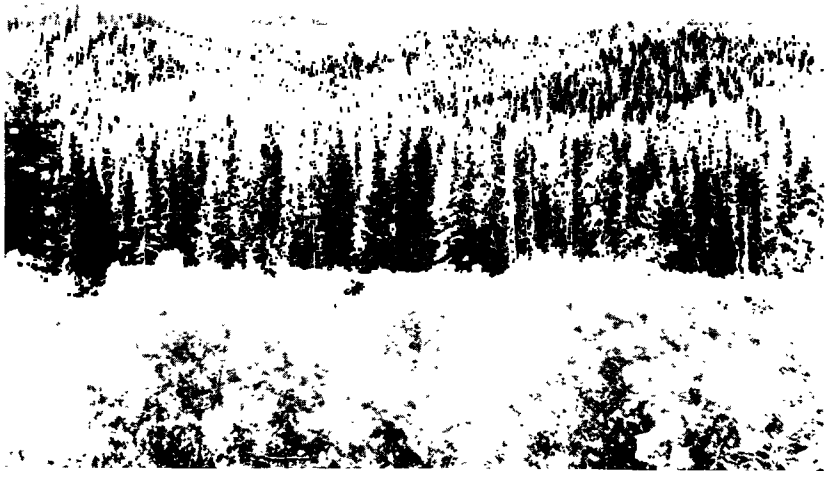


A LARGE SUGAR PINE TREE RECENTLY KILLED BY THE MOUNTAIN PINE BEETLE IN THE STANISLAUS NATIONAL FOREST, CALIF SEPTEMBER 1935.

Usually such large trees are not killed by this beetle in a single year, two or more attacks often being suffered before the entire stem becomes infested



1. IN A LODGEPOLE PINE GHOST FOREST OF YOSEMITE NATIONAL PARK, CALIF
These trees were all killed by the mountain pine beetle in an epidemic lasting only 4 years. 1915



2. INFESTATION OF THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE
Insect-killed trees show white in photograph Bitterroot National Forest.



1. TREATING WHITE PINE TREES INFESTED WITH BROODS OF THE MOUNTAIN PINE BEETLE BY BURNING DECKS OF INFESTED LOGS



2. TREATING WHITE PINE TREES KILLED BY THE MOUNTAIN PINE BEETLE BY PEELING BARK FROM INFESTED PORTION OF BOLE

When exposed, the insects are destroyed by ants and small mammals.



1. BARK BEETLE INFESTED LODGEPOLE PINES SPRAYED WITH OIL AND BURNED TO KILL THE BROODS BENEATH THE THIN BARK.



2. PONDEROSA PINE ON THE KLAMATH INDIAN RESERVATION IN OREGON. SEVERELY DEFOLIATED BY THE PANDORA MOTH IN THE EPIDEMIC OF 1918-26.



1. "FLAGS" ON A *PONDEROSA PINE TREE* CAUSED BY THE PINE MIDGE (RETINODIPLOSIS).

This insect kills the terminals causing a decided set-back in growth. It is generally distributed throughout the pine regions of Oregon and California. Keno, Oreg., 1926.



2. LEADER OF WHITE PINE TREE DESTROYED BY THE WHITE PINE WEEVIL PISSODES DUBIUS.

After the terminal is killed several of the laterals compete for dominance, which results in a poorly formed ("cabbage pine") tree worthless for timber purposes.



1. PANDORA MOTH (COLORADIA PANDORA) A DEFOLIATOR OF PONDEROSA LOGDEPOLE, AND JEFFREY PINES IN OREGON AND CALIFORNIA.



2. VARIOUS STAGES OF THE SPRUCE BUDWORM (CACOECIA FUMIFERANA). EGGS ON LEAF, LARVAL INSTARS, PUPAE, CAST PUPAL SKINS AND ADULT MOTHS.



1. AUTOGIRO IN ACTION SPRAYING CONCENTRATED OIL-LEAD ARSENATE MIXTURE OVER RED PINE PLANTATION INFESTED WITH NEODIPRION SERTIFER.



2. LARVAE OF THE EURCPEAN SPRUCE SAWFLY (DIPRION POLYTOMUM) MASSED UNDER THE TREES THEY HAVE DEFOLIATED

These larvae fall to the ground after the foliage is consumed in their search for additional food

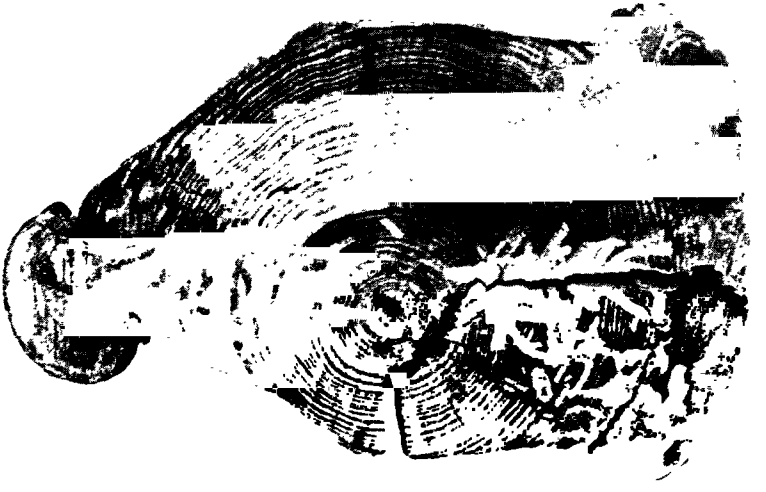


SCOLYTUS MULTISTRIATUS, THE VECTOR OF THE DUTCH ELM DISEASE.

Adult, eggs, larval tunnels, larva, pupa, exit holes and feeding scars, and point where tree is inoculated with the disease.



1. TYPICAL WIND-THROWN STAND OF LONGLEAF PINE FOLLOWING POOR TURPENTINING PRACTICES AND SUBSEQUENT ATTACK OF THE TURPENTINE BORER



2. THE TURPENTINE BORER (BUPRESTIS APRICANS) ATTACKS THE BASES OF TURPENTINE LONGLEAF PINES AND SO RIDDLES THE WOOD WITH THE LARVAL MINES THAT THE TREES BREAK OFF

GROWTH HORMONES IN PLANTS[1]

By KENNETH V. THIMANN

Harvard Biological Laboratories, Cambridge, Mass.

[With 2 plates]

The development of our knowledge of the plant hormones is a very interesting example of how a piece of research which seems purely academic may lead to results of considerable practical importance. It also demonstrates rather well the reason for the fascination of scientific work, because one never knows quite where one is going to be led next. Almost any research problem becomes a kind of chase, with all the excitement of an old-time comedian's chase, which may embroil him in all kinds of difficulties and may finally land in the most unexpected places.

No scientific story, of course, has a true beginning, for they all grow out of some earlier one, but this may be regarded for the present as beginning in 1919, when Professor Paál, in Hungary, was studying the response of certain seedlings to light. For this work he used the coleoptiles of the cereals, especially oats.

In a field of oats or wheat, when the crop is still young, one may often see a thin, papery sheath at the base of the stalk. It is soon torn open by the leaves which grow up through it, and withers early. This delicate shoot first attracted the attention of Charles Darwin by its extreme sensitivity to light, and since Darwin many others have studied it. Now Paál was interested in the effect of the extreme tip of the coleoptile on the sensitivity of the part below it. He was anxious to confirm the earlier finding of Boysen-Jensen (1913), which was that if the tip is removed, the sensitivity to light—as shown by the curving of the coleoptile toward the source of light—was lost, and that when the tip was replaced (not grafted but just glued on) this sensitivity returned. He not only did confirm this, but found something even more important. If the tip which had been cut off

[1] Presented at a meeting at the Franklin Institute March 9, 1939. Reprinted by permission from the Journal of the Franklin Institute, vol. 229, No. 3, March 1940.

was stuck on again a little to one side, the side on which it rested grew more than the opposite side, with the result that the plant curved (fig. 1). No light was here involved; the curvature was due to the one-sided influence of the tip. Paál deduced that the growth of the shoot was controlled by a growth substance or hormone which was produced by the tip.

Now the idea of hormones was developed by zoologists to account for those phenomena in which one organ influences tissues in other parts of the body. The heroine of the dime novel, who is suddenly confronted by the villain, or by the family ghost, turns as white as a sheet, her hair stands on end, and her eyes widen with horror. These effects result from her having received a dose of a hormone (adrenalin) which is secreted in a special gland and travels about

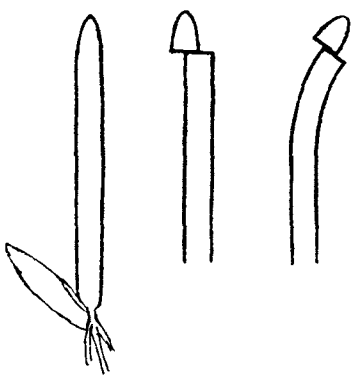


FIGURE 1.—The experiment of Paál. Left, intact seedling; center, tip removed and replaced to one side; right, curvature resulting.

in the blood stream, causing the capillaries to contract all over the skin and scalp. Many other hormones are known. All of them are secreted in some part of the animal body and travel about it to exert their effects in other parts.

In this case growth is controlled by a substance or hormone secreted by the tip and traveling down the side of the plant, which responds by growing faster. In the normal plant, with the tip symmetrically placed, all sides would receive the same amount of the hormone and consequently would grow equally.

It was 10 years before the next step forward was taken by Went, in Holland (1928). He found that if the tips were cut off and placed on a jelly of agar or gelatin, this jelly acquired the property of hastening the growth of a coleoptile stump when applied to one side of it. The growth-promoting hormone had diffused from the tip into the agar. The curvatures which resulted were very regular, and Went found that under constant conditions the reaction could

be used as a test for the hormone (fig. 2). Agar pieces of controlled size were used, and the curvature of the plants measured after a definite time. The curvature was then proportional, within certain limits, to the amount of hormone which must have entered the agar.

Instead of placing the agar on one side of the coleoptile stump it can be placed symmetrically on it, thus taking the place of the tip, with the result that the coleoptile grows faster on all sides. With a traveling microscope the straight growth can also be used for the assay of the growth hormone. This is important in principle, but the curvature method has certain technical advantages for use as a routine test.

Now there are a good many natural conditions under which plants curve. Plants are not free to move about as the higher animals are, since their base is usually fixed. When one is confined to bed by doctor's orders, one's base is similarly fixed, and about all that one can do, when receiving visitors, is to curve in various ways.

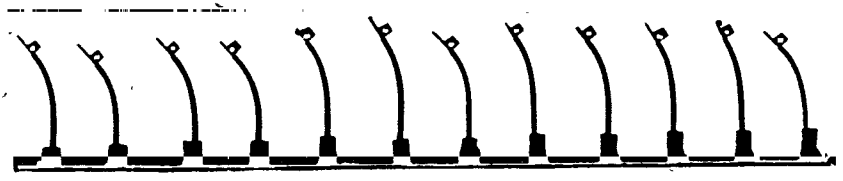


FIGURE 2.—Oat seedlings with tips removed and blocks of agar containing growth hormone applied. Photographed 100 minutes later.

Plants curve in particular in response to light and gravity. In these curvatures there is a characteristic difference between the response of the shoot and that of the root. Shoots curve toward a weak light, while the roots are either indifferent or (in some plants) curve away from the light. Shoots curve upward away from the earth, roots typically downward. As mentioned above, it was from studies of the curvature toward light that the role of the growth hormone was discovered. Naturally, therefore, it occurred to these workers that the curvatures caused by asymmetric application of the growth hormone are probably related to those due to light and gravity. Cholodny, in Russia (1927), suggested that all such curvatures were due to a displacement of the hormone within the plant, more going to the lower side when the plant is placed horizontal, or to the shaded side when exposed to a one-sided source of light. That this is the correct explanation was proved in the following way: tips were cut off and placed on two small pieces of agar so that the hormone diffusing from the two sides would be collected in separate pieces. On now exposing to light from one side, the agar on which the dark side rested was found to contain more growth hormone than the

other. The amounts of growth hormone were determined by applying the agar to other plants from which the tips had previously been removed, and measuring the curvature. In the same way tips were placed horizontal and the agar in contact with the lower side was then shown to have more hormone in it than that in contact with the upper side. (See fig. 3.) These experiments have since been repeated in a variety of plants and they leave no doubt that this is at least the major factor in the production of such curvatures.

It was not long before chemical work on the nature of the hormone was undertaken. This was made possible by the discovery that it is present, in much larger quantity than in the coleoptile tip, in cultures

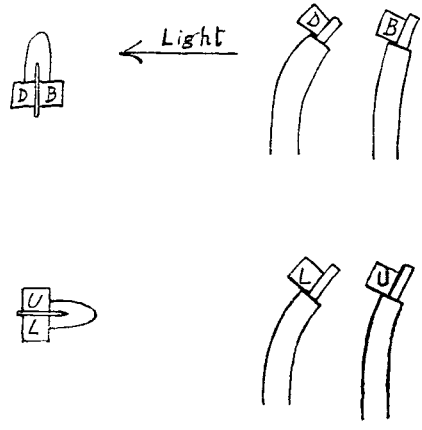


FIGURE 3.—Above, light coming in direction of arrow causes more hormone to diffuse out from the dark side, *D*, than from the bright side, *B*; below, gravity acting on the tip placed horizontal causes more hormones to diffuse out from the lower side, *L*, than from the upper side, *U*.

of some bacteria and fungi, and in human urine.[2] Kögl and Haagen Smit, in Holland (1931–34), isolated three active substances from urine and also from corn seeds, while I isolated (1935) the substance produced by the fungi and found it to be identical with one of their compounds. Since then other active compounds have been synthesized, and we now have a variety of these substances, which all have about the same effect, though in different degree. They have been called "auxins."

While this work was developing we made a survey of the distribution of auxin in the whole plant. It was found that it is formed mainly in growing buds and in young leaves. This had an important sequel. As is well known, plants usually have a "leader" or terminal bud. If this is cut off, one of the other buds begins to

[2] More than 10 million coleoptile tips would be required to prepare 1 milligram of the hormone.

grow and soon becomes the leader. In other words, this bud was capable of growing all the time, but did not do so because the terminal bud was present; i. e., it was inhibited by the terminal bud. Now since the terminal bud produces relatively large amounts of auxin, Skoog and I made the experiment (1934) of removing this bud and putting in its place a supply of auxin. The buds below were then inhibited to the same extent as they would have been by the terminal bud. The auxin which this bud produces, then, has two functions: it causes the stem below it to grow, and it causes the buds below it to be prevented from growing. This is the first example of what was later found to be very general, namely, that auxin elicits different responses from different plant parts. Although normally it causes the stems to grow while the buds are inhibited, it must not be thought that this is simply a balance or a compensation of growth, i. e., that if the stem grows the buds do not and vice versa. For we found that it is possible by using the right conditions to prevent the growth of the buds without causing the stem to increase appreciably in length. In other words, the inhibition is quite independent of other growth processes.

At the same time that this work was done we were engaged in the study of another problem. It is known that isolated parts of stems, i.e., cuttings, form roots under certain conditions. Generally cuttings root better if young buds or leaves are on them. On this account it was thought possible by van der Lek and by Went (1929) that the formation of roots is controlled by a hormone. Went and I (1934) soon found that certain preparations when applied to cuttings which otherwise were not in the condition to root (having been kept in the dark) caused rooting, and that the number of roots formed could be made roughly proportional to the concentration of the material used. Work was therefore begun on the purification and isolation of the active root-forming hormone. It was not long before it became clear that the richest sources of this were the same materials which had proved the rich sources of auxin, namely urine and the cultures of fungi already mentioned. On successive stages of purification of the root-forming hormone, its activity always went along with the auxin activity. Finally we became convinced that the root-forming hormone is identical with the growth hormone, auxin. This was proved when we synthesized an auxin (indole-acetic acid, which Kögl and Haagen Smit had just isolated from urine and shown to be an auxin) and found it to be highly active in producing roots. Furthermore, the production of roots, like the promotion of growth, is general and not limited to special groups of plants, so that the use of auxins by nurserymen in promoting the rooting of cuttings has since that time become widespread. Several synthetic auxins have been marketed for this purpose.

Although the results of auxin treatment in rooting of cuttings are in general very striking, there are some plants which do not respond markedly even to this. Recently we have studied some of these so-called "difficult" plants. It appears that some of them, such as Canadian hemlock and blue spruce, may be readily rooted if care is used and auxin in the right concentration is applied (pl. 1). Some others, such as white pine and Norway spruce, can also be rooted, but only when the plants from which cuttings are taken are themselves young (pl. 2). It is important to note that it is not the age of the cutting which is important, but the age of the tree from which it is taken. Occasionally, too, other substances, such as sugar, vitamin B_1, etc., when used together with auxin, promote the formation of roots.

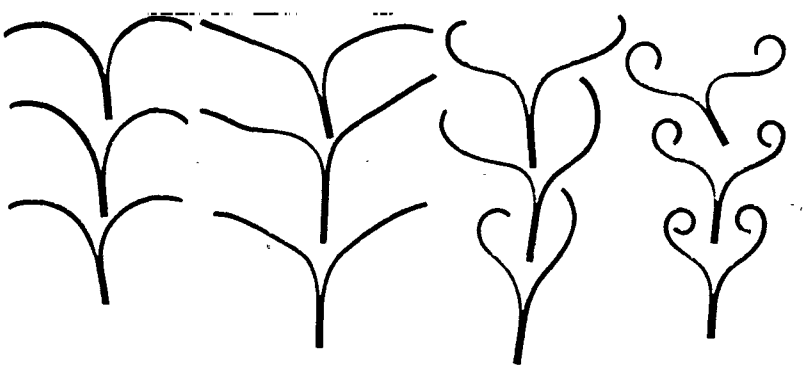


FIGURE 4.—Inward curvature of slit stems in auxin solutions. Left to right: water, 0.2, 1, and 5 mg. auxin per liter. Photographed after about 30 hours.

Another fact of some importance in the rooting of woody cuttings is the type of shoot used. In some of the conifers it is clear that there is a difference in response between the side shoots (laterals) and the apical or terminal shoot. The latter, even if supplied with sufficient auxin, roots less readily and dies more quickly than the side shoots. Thus here again the response to auxin varies with the part of the plant.

Perhaps the most remarkable variation within the plant is shown by the different responses of different parts within the same section of stem. If stems of young pea plants are slit in two and placed in auxin solution, the two halves curl inward toward each other. The extent of the curvature varies with the concentration of the solution, and the reaction can thus be used as a test for the auxins (fig. 4). Many other plants show the same phenomenon; dandelion stalks are very responsive. The development of the curvature can best be shown in the form of a movie, taken by lapse-time photography. The halves

first curve outward, then after an hour or so the inward curvature begins and is complete in about 20 hours.

Now in this reaction the auxin is being supplied to all the tissue, since the piece of stem is immersed in the solution, yet nevertheless the curvature which results shows that the tissues on the outside grow more than those on the inside. It is evident that this phenomenon is quite different from those described at the beginning, in which curvature results because the auxin is only applied to one side. We have accumulated a good deal of evidence to prove that here there is truly a difference in the response of the outer and inner sides to the same auxin concentration.

Such subtle differences as this between closely appressed layers of tissue, or those described above between the rooting response of different parts, can now be investigated for the first time by the use of growth hormones. These substances are a powerful tool for studying all kinds of phenomena in plants and especially that most obscure process of all, whose understanding is one of the most fundamental things with which biologists are concerned, the phenomenon of growth.

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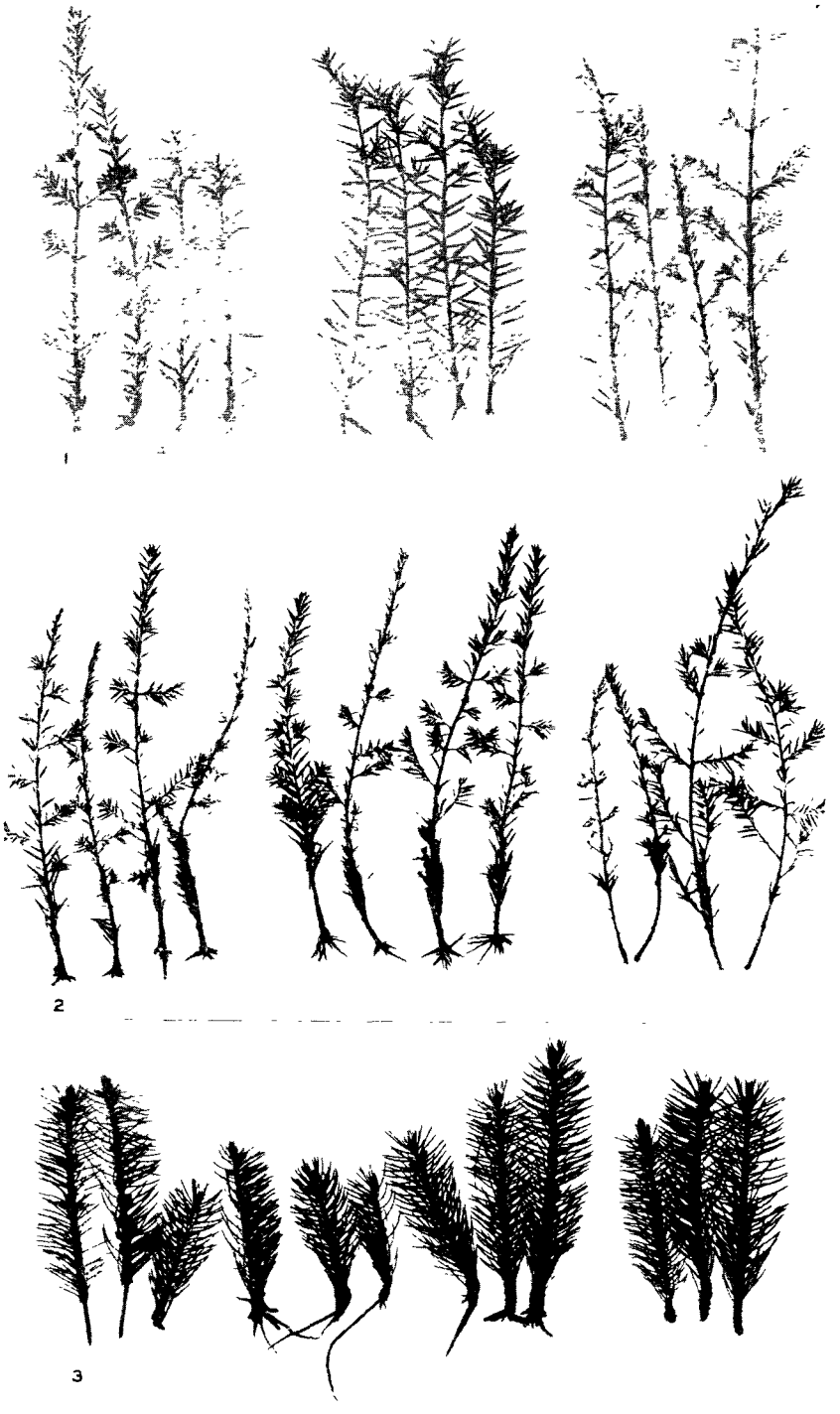
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Top, Canada hemlock Left to right, 400, 100, and 0 mg auxin per liter for 24 hours
Middle, Canada hemlock, variety *pendula*. Left to right, 100, 50, and 0 mg auxin per liter for 24 hours.
Bottom, Blue spruce Left to right, 400, 200, 100, and 0 mg. auxin per liter for 24 hours All photographed after 9–10 weeks in peat-sand medium. (From Thimann, K V, and Delisle, A. L, Journ. Arnold Arboretum, vol. 20, pp 116–136, 1939)



WHITE PINE.

Left to right: Above, 0 and 100, below, 200 and 400 mg. auxin per liter for 24 hours. Photographed after 4 months.

USEFUL ALGAE

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[With 9 plates]

ALGAE AND THE ANCIENTS

The earliest mention of algae that we can find in the Chinese Classics is strangely enough an economic one, thereby discrediting Virgil's famous words, "vilior alga" or "useless seaweed." In the Book of Poetry, the Chinese song words which have a datable range between 800 and 600 B. C., the following ode occurs:

THE DILIGENCE AND REVERENCE OF THE YOUNG WIFE OF AN OFFICER, DOING HER PART IN SACRIFICIAL OFFERINGS

She gathers the large duckweed,
By the banks of the stream in the southern valley.
She gathers the pondweed,
In those pools left by the floods.

She deposits what she gathers,
In her square baskets and round ones;
She boils it,
In her tripods and pans.

She sets forth her preparations,
Under the window in the ancestral chamber.
Who superintends the business?
It is [this] reverent young lady.

In Legge's translation of this poem which is given above, the words "pondweed" and "duckweed" are designated in the original Chinese version by the character for algae. From this poem we can assume that even in the time of Confucius algae were considered a food of great delicacy, even a worthy sacrificial offering to the ancestors since the ancestral chamber is known to be the room behind the temple specially dedicated to the ancestors.

Algae were also considered an emblematic figure, for in the classical Book of History, the Chinese character for algae occurs in the following, where Legge translated it as "aquatic grass":

The emperor: "I wish to see the emblematic figures of the ancients—the sun, the moon, the stars, the mountain, the dragon, and the flowery fowl, which are depicted *on the upper garment*; the temple cup, the aquatic grass, the flames, the grains of rice, the hatchet, and the symbol of distinction, which are embroidered *on the lower garment.*"

Another use of the beautiful forms of algae as decoration is described again in the Chinese Classics as follows:

The Master (Confucius) said, "Tsang Wăn kept a large tortoise in a house, on the capitals of the pillars of which he had hills made, with representations of duckweed on the small pillars *above the beams supporting the rafters.*"

We also find in the Confucian Analects:

The capitals of the pillars in the grand temple with hills carved on them, and the pondweed (*tsao*) carving on the small pillars.

In their writings and speech, the Chinese use the character for algae to describe a thought where the meaning of elegant, or fine composition is implied, thereby showing their appreciation of the delicate and intricate morphology of the algae plants.

Algae, or seaweed, are described in the Materia Medica of the Ancient Chinese as follows: "Whole plant is officinal. Taste bitter and salt. Nature cold. Nonpoisonous." "The *hăi tsao* (algae) grows in Tung hai (Shantung) in ponds and marshes. It is gathered on the seventh day of the seventh month and dried in the sun." "It grows on islands in the sea, is of a black colour, and has the appearance of flowing hair." Then in the eighth century:

There are two kinds of *tsao*. The *ma wei* (horse's tail) *tsao* grows in shallow water. It looks like a short horse tail, is fine-leaved and black. Before use it must be steeped in water to remove the brackish taste. The other kind has large leaves and grows in the deep sea near the Kingdom of Sin lo. The leaves are like those of the *shui tsao* but larger. The sea people having attached a rope to their waists glide down to the bottom of the sea and so secure the seaweed. Owing to the appearance of a large fish, dangerous to man, it cannot be gathered after the fifth month. This plant is mentioned in the *Rh ya.*

Then there is an alga with verticillate leaves called "hair-of-the-head vegetable." "*Kun pu* (a kind of algae) is produced in the Eastern Sea. It is twisted into rope like hemp. It is of a yellowish black colour, soft but tough and edible. The *Rh ya* calls it *lun.*"

Still in the eighth century:

The *kun pu* is produced in the Southern Sea. The leaves are like a hand, large, and of a purplish red colour. This plant undulates [in the sea]. The foreigners (Coreans) twist it into ropes, dry it in the shade, and carry it by ship to China. All the different sorts of *hai t'sai* (seaweed) resemble each other in quality and taste, and their medical virtues also are much alike.

Several kinds of algae were used by the ancient Chinese as food. The large seaweed called *Laminaria saccharina* and *Gracilaria lichenoides* commonly known as Ceylon moss are mentioned as articles of food in the Chinese Materia Medica. The Chinese regarded a seaweed diet as cooling but rather debilitating if pursued for a long time. Both as a food and a medicine was used *Porphyra coccinea* which is described in the Chinese Materia Medica as follows:

> This algal plant is a sort of laver which is green when in the fresh state and purple when dry. It grows on the seashore of South China and the Fukienese gather it and press it into cakes. It is not poisonous, but when taken in excess produces colicky pains, flatulence, and eructation of mucus. It is recommended in diseases of the throat, especially goiter.

The Pêntsao recommends all of the medicinal algae in the treatment of goiter. A seaweed called k'un-pu was recommended for dropsies of all kinds. Gillur-Ka-putta, a dried seaweed collected near the mouth of the Saghalien River was highly prized in upper India as a remedy for bronchocele. Lung-shê-ts'ai (dragon's tongue) was used as an application in the treatment of abscesses and cancers. *Gracilaria lichenoides* was utilized as a demulcent in intestinal and bladder difficulties. Practically all the medicinal properties of plants are attributed to the semimythical Shên Nung, known as the First Farmer or Father of Husbandry and Medicine, and who purportedly lived in 3000 B. C.

Virgil, the prince of Latin poets, who lived from 70–19 B. C., used the phrase "vilior alga" meaning "more vile or worthless than algae." Algae grew in great abundance about the Island of Crete. When it was torn by the violence of the waves from the rocks where it grew and was then tossed about the sea and finally cast upon the shore, it became altogether useless, lost its color, and presented an unseemly appearance. Again, in another passage, Virgil writes of seaweed beaten back against the shore by the waves. Evidently, seaweed had no value whatsoever in his experience.

Horace (65–8 B. C.) shared Virgil's poor estimation of algae. In his Satires he writes: "But birth and virtue unless [attended] with substance, is viler than seaweed"; and again, "Tomorrow a tempest sent from the east shall strew the grove with many leaves, and the shore with useless seaweed, unless that old prophetess of rain, the raven, deceives me."

However, Pliny the Elder (A. D. 23–79), the Roman naturalist, speaks of garments dyed purple with "phycos Mallasion," a seaweed like lettuce. He also uses the word "fucus" for dye. Then he uses the word "algensis," meaning that which supports itself or lives upon seaweed.

In his Epigrams, Martial (A. D. 50?–102?) writes of "all the swarthy Indian discovers in Eastern seaweed," meaning pearls.

WHAT ARE ALGAE?

The word "alga" (singular), "algae" (plural) comes from the Latin and is used by us to designate the large class of plants, the algae, which are the lowest and simplest in organization of all the plants in the plant kingdom. The algae, like all the plants with which we are familiar, possess chlorophyll, or green pigment, and are thus able to make their own food from inorganic materials such as carbon dioxide, water, and certain mineral substances with the aid of light. Alga is derived from the Latin word "algor" which means "cold."

The algae include the seaweeds and unicellular and multicellular green plants that do not possess a true stem, a true root, true leaves, or true seeds as are found in the higher plants. All of the life processes of the algae—respiration, photosynthesis (the manufacture of their food), and reproduction—are organized within their cells. Although they do not have true organs—root, stem, leaves, and seeds—they possess the green pigment called chlorophyll which is characteristic of plants and essential for the production of their food.

The lower algae include plants whose whole framework consists of an individual, isolated cell such as the Diatomaceae, Desmidiaceae, and Palmellaceae. Every function of life is performed within the cell: the assimilation of gases and salts, the manufacture of their own food, and growth until the cell reaches the size proper to its species. Then the nucleus within the cell gradually separates into two portions and at the same time a cell wall is formed between each portion, thus forming two cells from the original one cell. These two cells do not adhere to each other as cells do in a compound plant, but each half-cell separates from its fellow and starts out on its own independent career: food manufacture, increase in size, division at maturity, and then separation of the contents occurs again. In spite of the fact that these infinitesimal plants are microscopic in size with their uniform and simple structure, they have an innumerable variety of exquisite and artistic forms, and the secrets of their mechanism are still puzzling and intriguing the scientists.

In other low forms of algae, the cell is cylindrical and sometimes lengthened into a threadlike body, or the lengthened cells are joined end to end as in the Oscillatoriaceae. There is a further advance in the Vaucheriaceae, where the filiform cell becomes branched without any interruption to the plant body; and these branching cells sometimes attain inches in length with the diameter of half a hair and constitute some of the longest cells among plants. In the nearest genera to *Protococcus* the frond is a roundish mass of cells which cohere irregularly by their sides; then more advanced are the Ulvaceae where the cells are arranged in a compact membranous expansion

formed by the lateral cohesion of a multitude of roundish polygonal (due to mutual pressure) cells that originate by the quadripartition of older cells (longitudinal as well as transverse division) so causing the cell growth to proceed nearly equally in all directions. In *Ulva*, or sea lettuce, we find the earliest type of an expanded leaf.

Similarly, the earliest type of a stem may be traced back to the cylindrical cells of the lower algae. In *Conferva*, whose body consists of a number of cylindrical cells fastened end to end, all continually originating by the continual transverse division of an original cylindrical cell, the frond or plant body continually lengthens but does not make any lateral growth. It consists of a series of joints and interspaces and correctly symbolizes the stem of a higher plant formed of a succession of nodes and internodes. In other genera, these confervoid threads branch and the branches originate at the joints or nodes like the leaves and branches of the higher compound plants. In still other genera of algae, the stems become flattened at their summits until leaflike parts are formed which again by the loss of their lateral membranes and by the acquisition of thicker midribs change back into stems. Among the most highly organized algae there are leaflike lateral branches that assume the form and, to an extent, the arrangement of the leaves of higher plants. But even when the leaflike bodies appear most highly developed in the algae, they are merely expanded branches as may be seen by observation of the gradual changes that take place in a young *Sargassum* seaweed as the frond lengthens.

The algal cells imbibe their food equally through all parts of their surface and the food is passed from cell to cell toward the cells that are assimilating more actively or growing more rapidly. The salts and gases that compose the food of algae are dissolved in the salt water or fresh water that surrounds the algal cells or they are in the air or dissolved in the water in the soil about the algae. For this reason the alga does not need a true root such as is found in the higher plants. Where a rootlike organ exists in algae, as in the larger seaweeds, it is a mere holdfast with the purpose of anchoring the seaweed to a stone or wooden base and thus preventing the seaweed from being driven about by the action of the waves. Ordinarily, in the smaller kinds of seaweeds, it is a simple disk or conical expansion of the base of the stem that is strongly fastened to the substance on which the seaweed is growing. In the gigantic oarweeds, or *Laminaria*, where the frond has attained a large size and offers a proportionate resistance to the turbulent waves of the ocean, the central disk is strengthened by lateral holdfasts or disks formed at the bases of side rootlike parts emitted from the lower part of the stem, just

as the tropical screwpine *Pandanus* puts out cables and shrouds to support the increasing weight of the growing head of branches. The branching false roots of the *Laminaria* are merely compound *Fucus* disks and in some few instances, as in *Macrocystis*, the grasping fibers of the rootlike part develop extensively and form a matted substratum from which many stemlike parts originate. The holdfast extends over the flat surface and adheres to it with no tendency to penetrate it as do the roots of higher plants. Only on unstable soil, as on the shores of the Florida Keys, do the rootlike holdfasts of the Siphoneae and the Caulerpeae penetrate into the sand, forming a compact cushion but in search of stability in the shifting sands rather than for food.

The four chief varieties of color observed among the algae are green, blue-green, olive green or brown, and red. They form an easy method for separating the algae into separate divisions since the classes of color are fairly constant among species that are allied physiologically and morphologically.

The green color of the Chlorophyceae, or green algae, and the blue-green color of the Cyanophyceae, or blue-green algae, is characteristic of the algae that grow either in trees, in the soil or on land, on rocks, in fresh water, and in the shallower parts of the sea where they are exposed to full sunshine but are seldom quite uncovered by water. About one-fourth of the green and blue-green algae found in deep water are as vivid a green as those found near the surface so that it cannot be assumed that the green color, as in land plants, is due to a perfect exposure to sunlight.

The brown algae, or Phaeophyceae, are most abundant between tide marks in places where they are exposed to the air at the recess of the tide, and are thus alternately parched in the sun and flooded by the cool waves of the returning tide. They may extend to low-water mark and form a broad belt of vegetation about that level. A few straggle into deeper water, sometimes into really deep water. The gigantic deep-water algae *Macrocystis*, *Nereocystis*, *Lessonia*, and *Durvillea* are olive-colored.

The red algae, or Rhodophyceae, are most abundant in the deeper and darker parts of the sea. They rarely grow in tide pools with the exception of pools shaded from the direct rays of the sun by an overhanging rock, or by overlying brown algae. The red color is always most intense and pure when the plant grows in deep water as may be observed by tracing the same species from the greatest depth to the least depth at which it is found. *Chondrus crispus* is deep-purplish red in deep pools near the low-water mark but in shallow pools where it is exposed to the sun's rays it fades to greenish or whitish shades.

Many species of seaweeds, fresh from the sea, can resist the action of fresh water while others instantly dissolve and decompose in fresh water.

In the lowest forms of algae where the whole body consists of a single cell, some cells gradually change and are converted into a spore or fruiting body without any obvious contact with other cells. More frequently, as in the Desmidiaceae and Diatomaceae, a spore is formed only by the conjugation of two cells or individual plants. When the two cells are mature, usually filled with darker-colored chlorophyll, they approach each other. A portion of the cell wall of each one is then extended into a tubercle at opposite points. The tubercles come in contact and become confluent as the cell wall between them vanishes and a tube thus connects the two cells. The contents of the cells are mixed through this tube and a sporangium, or new cell filled with spores, is formed either in one of the old cells or at the point of the connecting tube. Then the old, empty cells die while the sporangium may remain dormant for a year or several years. These sporangia which are formed in abundance at the close of the growing season become buried in the mud at the bottom of pools where they are encased when the water dries up in the summer, then in the spring with the return of water they develop new fronds.

The filamentous algae of the pools and ditches also form new plants in this manner. Almost every cell of these filaments is fertile and when two filaments are joined together a series of sporangia will be formed on one filament while the other is converted into a string of dead, empty cells.

In the highest algae there appear to be two sexes. The sporangium is fertilized when it is in its most elementary form and when it cannot be distinguished from an ordinary cell. The fertilizing organs are called antheridia and are most readily seen among the Fucaceae.

Besides reproducing by single spores many algae have another and sometimes a third means of reproduction.

As has already been mentioned, the simplest algae divide by the division of a single cell into two cells.

In the green algae, the homogenous, semifluid consistence of the cell becomes granulated. The granules detach themselves from the cell wall and float freely in the cell. At first they are irregular in shape but gradually they become spherical. They congregate in a dense mass in the center of the cell and a movement similar to that of bees around their queen commences. One by one the active zoospores detach themselves from each other and move rapidly about in the vacant space in the swarm cell. They continually push against the cell wall until it is broken, when their spontaneous move-

ments continue for some time in the surrounding fluid. The zoospores become fixed to a submerged object where they proceed to develop cells and grow into algae similar to the ones from which they originated.

NATURE'S UTILIZATION OF ALGAE

Now when algae are used in myriad ways in food, agriculture, industry, medicine, photography, and even in cosmetics, it seems strange that, considering the great quantity of them growing all over the world in the ocean as well as in fresh water and on land, their full usefulness has been so slowly realized by man. Wise old Mother Nature has always allotted them their role in her scheme of life although man has been tardy in recognizing it and in applying her methods of their utilization to his own needs.

The great abundance of algae in the sea and on the land is not merely an indication of nature's generosity. The microscopic and visible algae that fill the ocean are there for a direct purpose whether man sees fit to utilize them or not. For the oceans are teeming with animal life varying in size from microscopic polyps to the mammoth whales which could not exist without the aid of the plant life. One of nature's many laws is that animal life requires nutriment prepared by the plant life, and plants are necessary to change the mineral constituents of their surrounding environment into available nutriment for the animals. In the sea, the algae are the only plants that can grow and therefore a large number of species of sea animals are directly dependent upon them for their food, while other species depend upon them indirectly. The algae are indispensable to the continuity of animal life in the sea. The green fat of the turtle and the green material present in the lobster are indicative of their source of nourishment—the algae.

There is a famous Chinese proverb:

> Big fish eat little fish
> Little fish eat shrimp
> Shrimp eat mud.

The so-called mud is full of microscopic algae. The alimentary canals of small and large fish have long been happy hunting grounds for biologists. The unicellular algae and diatoms are the salad of the water. They are so minute as to be available for the consumption of the smallest animal organisms, and yet, because of their abundance, they may represent the sole food supply of some of the larger forms of fish. They are highly nutritious, and not one among the thousands of living species is deleterious. The abundance of the plant growth in the water is responsible for the abundance of the fish supply. Dr. Albert Mann, the noted diatomist, examined the stomach contents of some young hake (fish about 5 inches in length).

The stomachs were filled with small herring. The herring in turn were gorged with two species of copepods; and the copepods were filled with diatoms and algae. As Dr. Mann pointed out: "Very clearly this chain of four links is equal to a sentence of four words. No diatoms, no hake."

Tiffany was able to identify 150 species and varieties of algae in the digestive tract of *Dorosoma cepedianum* (gizzard shad) which he observed to be a highly vegetarian fish. In a similar study made by Coyle, 128 species of algae were determined in another fish, *Pimephales promelas* (the fathead minnow). Two other species of minnows, *Notropis procue* and *Exoglossum maxillingua*, are also known to consume much vegetable matter including filamentous algae and diatoms. These minnows are food for the game fish.

The cultivation of *Bangos* in the Philippines has been described in detail by Adams, Montalbin, and Martin. Lab-lab is the name given to the food of the fry of the milkfish. It is composed of unicellular, colonial, and filamentous blue-green algae, unicellular green algae, diatoms, bacteria, protozoa, minute worms, and small crustaceans. The pond bottom is cleaned two or three times by flowing water freely into it and out of it. The pond is then exposed to sunshine for 2 or 3 days. When the pond bottom is dry, water is turned into it to a depth of 3 to 5 centimeters. The lab-lab develops in 3 to 5 days, then the water is increased to a depth of 12 centimeters. The fry feed on the lab-lab and, when they are older, on the filamentous green algae that develop over a depth of 12 centimeters. The algae thrive especially where the water is brackish. Mullet also feed on the algae.

Velasquez has studied the algae in the digestive tract of *Dorosoma cepedianum* (the gizzard shad) in an effort to ascertain the ecological balance of fish ponds in which vegetarian fish are an important part of the fauna. He observed that the overstocking of fish ponds in the Philippines is often followed by a great predominance of blue-green algae which give the fish a bad taste. He found by culturing the stomach contents of the fish that the digested algae which had been present in the water supply but were not viable and so did not appear in the cultures were Bacillariaceae (diatoms), Volvocaceae, Dinobryon of the Heterokontae, and filamentous green algae. On the other hand, 30 species and varieties of Chlorophyceae, 12 species and varieties of Myxophyceae, 4 species of Bacillariaceae, 2 species of Heterokontae, and 1 species of Euglenophyceae passed undigested through the digestive tract. His investigation indicates that one of the sources of selective increase of certain algae in nature, and conversely, of the decrease of others, is due to the vegetarian fishes.

It should also be emphasized that the presence of a plentiful supply of plant life (algae) in waters where there is an abundance of fish is also of importance in regulating the balance of carbon dioxide and oxygen. Since the algae use in the production of their food a large amount of carbon dioxide which is given off by the fish, and the fish need a large amount of oxygen which is given off by the algae, the two forms of life derive mutual benefit from their association.

Of great importance in nature is the effect of algal growth on air and water. But before developing this subject further, it seems necessary to describe briefly the food substances and conditions necessary for the growth of algae. We already know that algae, like other plants, need certain essential elements for their growth. Calcium is not essential for many algae, but certain of them are unable to develop without it. Calcium, potassium, and magnesium are important because their bicarbonates furnish a supplemental supply of carbon dioxide for photosynthesis, which is the production of sugar from water and carbon dioxide taking place by the action of chlorophyll in light. During this process, a part of the oxygen is set free, thus providing oxygen for the respiration of animals which in turn throw off carbon dioxide for the plants. It should also be mentioned here that algae also use nitrogen in the form of nitrates, nitrites, or ammonium compounds. A small quantity of iron is also essential to their growth. Under certain conditions, the nature and quantity of the available calcium, magnesium, potassium, nitrogen, and iron compounds have a direct influence upon the existing type of algal flora just as the varying diets of the different races of people affect their characteristic appearance and habits.

Light, owing to the fact that it is essential for photosynthesis, would seem to be an important factor in the environment of algae. But algae differ markedly in their tolerance of light intensity, as has been shown by our experiments here at the Smithsonian Institution. Provided their food is prepared and in available form, some algae exist in a green condition in the depths of the earth and the ocean with a very small amount of light. The intensity of light that is available for plants growing under water below a depth of 1 meter decreases more or less uniformly with the depth. The turbidity of the water also has an effect on the quality of the light. Water absorbs energy in the infrared and red regions of the spectrum to a much greater extent than in the blue region. As a consequence plants in clear water receive a relatively large percentage of light within the region 4,400 to 5,800 Angstroms. Most plants cannot survive indefinitely in light intensities too low to permit sufficiently rapid photosynthesis to balance the carbohydrates used up in respiration.

The depth at which the compensation point occurs depends on the species as well as on the quantity of light available. The point at which photosynthesis just balanced respiration for certain algae was found to occur from 7 to 20 meters in turbid water and at 30 meters in clearer water. The optimum location for photosynthesis in the lakes of northern Wisconsin was found to be at the surface on cloudy days and at a depth of about 5 meters on fair, bright days. The brown and green algae require higher light intensities for a photosynthetic balance than the red algae. The ability of the red algae to live at greater depths than the green or brown algae may be due to the fact that the red algae absorb a greater percentage of blue light.

Temperature has an important effect on the acceleration or retardation of growth and reproduction, and under exceptional conditions the temperature of the habitat restricts the algal population to certain species.

The quantity of water or moisture necessary for algal growth varies, as may be seen, from the large amount required by the plants that live submerged in the ocean to the infinitesimal quantity at the disposal of the aerial algae.

The essential part that algae play in the life cycle of animals, which is their use of carbon dioxide and their throwing off of oxygen in the free state, keeps the water surrounding them pure. A large amount of oxygen is also yielded to the atmosphere during their processes of growth. It is a well-known fact that, whenever land becomes flooded or wherever an extensive surface of either salt or fresh shallow water is exposed to the air, Confervaceae and other allied forms of algae quickly multiply. Stagnant pools and ditches as well as water standing in urns or flowerpots in the open air quickly fill up with green scum and green silken threads. This scum and these threads cannot grow without emitting oxygen, and on a sunny day, the bubbles of oxygen can be observed to collect where the scum or threads are massed together. The oxygen continually passes off into the air while the algae usually vegetate vigorously, one species succeeding another as long as the water remains. When the land or the container dries up, the algal bodies, which are merely membranous skins filled with fluid, shrivel and are carried away by the wind or form a papery film over the surface of the soil or the container. The majority of species do not cause the air about them to become obnoxious by their decomposition. Each small individual cell does not yield a great deal of oxygen, it is true, but the aggregate yield from the algal cells is vast when we take into consideration the extensive surfaces of water spread over the earth. Nature has placed

her lowest form of plant life in them to help maintain a pure and healthy atmosphere.

Moreland (1937) writes of the puzzlement of the inhabitants in certain sections of Louisiana when they observed unusual deposits of thick, cobwebby, or paperlike material hanging from weeds and other vegetation after the spring floodwaters of the Atchafalaya and Ouchita Rivers had receded (pl. 1). In one section, near Jonesville, La., the paperlike deposit not only clung to vegetation but covered the ground and fences which looked as if they were covered with snow. When an examination was made of the material which appeared microscopically to be composed of unbranched filaments interwoven similarly to the fiber of lens paper, it was found that the substance was formed by the luxuriant growth of certain species of green algae including filaments of *Tribonema*, *Oedogonium*, and *Spirogyra*. The overflow water which was almost free of sedimentation had come early in the season when the temperature was especially favorable for the growth of these algae. Undoubtedly, the air over these flooded lands was purified by their presence.

It has also been shown by scientists that certain algae play a role in the nitrogen cycle in the soil. They do this directly by fixing gaseous compounds and indirectly by supplying nitrogen-fixing bacteria, especially *Azotobacter*, with available carbon compounds, produced by algal photosynthesis, and which are used by the bacteria as sources of energy necessary for the fixation process. Both green algae and blue-green algae can stimulate the activity of nitrogen-fixing bacteria. Very recently it has been definitely established that certain species of blue-green algae can fix atmospheric nitrogen in the light though not in darkness. However, their practical importance in the nitrogen economy of the soil remains to be determined since there is little known concerning the distribution and abundance of these algae in the soil and the conditions which determine natural fixation.

Algae have for some time been recognized as nature's pioneers in plant succession, and for that reason are now assuming importance in man's efforts to control erosion.

Treub describes the manner in which slimy layers of algae appeared over the surface of cinders and rocks on the Island of Krakatau 3 years after a volcanic eruption which had denuded the island of all visible plant life. By the growth, death, and decay of these algae, the island surface was rapidly prepared for the growth of mosses, ferns, and higher plants. Fritsch believes that an algal covering on the surface of dry, sandy soil regulates the moisture of the soil and thus provides a shelter for seed plants.

Graebner listed the species of soil algae found in a plant community as a whole on the heaths of northern Germany and ascribes to them great importance since they are the first immigrants on new soil and cause the first formation of humus in poor soil. He enumerated 31 species of Cyanophyceae, three species of Diatomaceae, and 18 species of Chlorophyceae found on these uncultivated heaths.

Fritsch and Salisbury described the succession of cryptogams (plants that do not bear true seeds) on burnt heath in England. The first immigrants were the green algae *Cystococcus humicola*, *Gloeocystis vesiculosa*, *Trochiscia aspera*, and *Dactylococcus infusionum*. Various fungi grow in their mucilaginous envelopes, and by degrees, lichens (a symbiosis of algae and fungi) appear. With the formation of lichen thalli, filamentous algae, *Mesotaenium violascens*, *Hormidium flaccidum*, and *Zygogonium ericetonium* appear.

The investigation of a single locality in east Greenland has shown that subterranean algae are present in the absolutely virgin soil there.

The soil in a rice field is inundated with water once or twice a year for a period of 8 to 12 weeks. Holsinger found a quantity of green and blue-green algae growing in this water.

Harrison and Aiyer have shown that a surface stratum composed of algae and other organisms in the irrigation ditches of rice fields plays an important part in the production of oxygen necessary for the growth of rice roots.

The cultivated paddy soils of the United Provinces (Benares, Mirzapur, Gorakhpur, and Basti) consisting of large tracts covering an area of at least 5,000 acres were investigated by Singh and found to contain 43 species of green and blue-green algae that were at a depth of 2 inches, 6 inches, and 12 inches. None were found in the wet fields. When the soils dried up, the blue-green algae were found to withstand desiccation longer than the green algae.

Algae can withstand drought better than the higher plants. This is illustrated during very dry periods in the summer when the grass is killed by drought. Piercy has shown that the green alga *Hormidium* which lives through periods of dryness will then begin to grow where the grass has been killed in the next succeeding damp period, usually in the springtime, and will spread extensively. The algae evidently help prepare the soil for the grass as numerous grass seeds then germinate and form a dense carpet of grass which will choke the algae and force them to disappear until the next summer drought.

Petersen and Puymaly have also described how the soil algae in a garden walk are constantly competing with the grass weeds that

crop up. Whenever the grass is weeded out, the algae attain a vigorous growth which gradually ceases with the renewed appearance of the grass.

Various scientists have described the presence of algal crust on large areas of soil during drought and how, by the addition of organic matter to the soil due to their decay, the land is made ready for the growth of grasses. Very recently, Booth (1941) has written of a series of scientific experiments that attempted to discover the use of algae in the control of erosion. Several species of algae belonging to the Myxophyceae grow in algal crusts on the residual Red Plains soils of central Oklahoma. This crust of algae forms during the wet seasons on sandy, wind-blown soil and is able to hold the soil in place during heavy winds. The crust is often broken by trampling and then is easily undermined which, together with covering by sand, leads to its final destruction. Hundreds of acres of badly eroded land in the south-central United States were chosen for study. The badly eroded land was due to overgrazing, to cultivating the land for a brief period and then abandoning it, or to frequent burning. Excessive erosion on the cultivated fields had changed the top soil so that the native climax plants were unable to become established until the slow process of plant succession and the building up of humus in the soil would recreate a suitable environment. In such places soil algae are of great importance as after a short time they are accompanied by mosses and annual seed plants. After study and experimentation on this area, Booth came to the conclusion that several species of soil algae constitute an initial stage in plant succession by the formation of a complete algal layer over these badly eroded acres. This plant cover may last for many years until higher perennial plants are able to form an abundant ground cover. The algal stratum does not slow down the rate of infiltration of water into the soil except in one case studied where there is a slight retardation for about the first 7 mm. of water. The soil losses from plots protected by the algal stratum were greatly reduced as compared with the losses from bare areas. The resistance of the algal crust to erosion is evidently the result of the union of the surface particles of soil into a nonerosible layer which is found to be very effective in breaking the force of falling water. Experimental tests indicated a higher moisture content in the top inch of soil which has had the protection of an algal layer, than in bare soil.

Fritsch sums up the chief benefits which the very important soil algae contribute as follows: Their faculty of withstanding drought without appreciable change and without the assumption of special resting stages; their ability to absorb atmospheric vapor as well as

water (liquid) thus enabling them to tide over periods of drought and to start growth as soon as wet weather begins; their successful competition with higher plants during drought; and the fact that after death they must form surface humus. The algae that grow in the soil to a depth of 6 inches surely must enrich it with the addition of organic material.

Not all of the marine algae are small, ornamental, delicate sea mosses or coarse, succulent, unattractive kelps or rockweeds, which have in both cases little substance remaining after their decay. There are many different kinds of marine plants that secrete lime from the sea water and are more or less hard and stonelike, although they form beautiful purple and lavender incrustations, so that their decay or continued upward growth is accompanied by a considerable increase in the height of the sea bottom where these plants are growing. The corals (animals) are, generally speaking, confined to the tropical seas, but the corallines (lime-secreting seaweeds which have a superficial resemblance to the corals) are more widely distributed. The fact has been known for years that the corals and other lime-secreting animals are active agents in building reefs and forming land, but only recently has it been noted that certain marine algae or seaweed, the corallines, have a function in the same great work. Kjellman has stated that off the shores of Spitzbergen and Nova Zembla *Lithothamnion glaciale*, a coralline, forms thick layers on the ocean floor at a depth of 60 to 120 feet in the water and that in the future formation of the strata of the earth's crust in these regions it will become of essential importance. Algae probably form the largest mass of the shell sands of Bermuda. Sir John Murray, in reporting the results of the famous *Challenger* expedition, has recorded that in three out of four samples of so-called coral sand or mud from Bermuda, over 50 percent of the mass has been composed of the calcareous seaweeds and their broken-down parts. Materials brought up by borings that were made to a depth of 1,100 feet in Funafiuti, a true coral island of the Ellica group, indicate that the lime-secreting seaweeds have been of greater importance than the corals in the formation of this island.

Nature's provision of vast beds or groves of giant kelp of the genus *Sargassum* of the order Fucaceae has been appreciated by voyagers since the time of the Phoenicians. Aristotle speaks of the weedy sea which they found at the termination of their voyage, and undoubtedly he was referring to the kelp. Columbus was the first voyager of modern times (September 16, 1492) to encounter it but it is possible that the same bank of seaweeds that he discovered was the one found by the Phoenicians. A great bank of *Sargassum* extends between the twentieth and forty-fifth parallels of north lati-

tude and in 40° W. of Greenwich which appears to occupy the same position today that it did in the time of Columbus. Between this bank and the American shores, there are various smaller areas and detached masses of this seaweed which are thrown into the ocean by the eddies caused by the subcircular motion of the great ocean currents. Humboldt computed that the whole of this area of seaweed in the ocean covered about 260,000 square miles, but not all this space is completely occupied with the floating seaweed. In many places there are spaces of clear water between distant and narrow ridges of the seaweed.

The geographical range of the Fucaceae is very extensive. It is found on the eastern shores of Europe and on the western shores of the American continent and in great abundance also off the shores of Japan and China. Later, we shall study more fully the economic importance which it has in industrial life. It is thought that it probably originated in rocks off the southern reefs and keys, where it was torn by the storms from the rocks and as it floated about in the ocean continued growth from its broken parts.

The giant kelp, as it is called on the Pacific coast, grows in such great abundance that it sometimes forms natural breakwaters for harbors, as at Santa Barbara, Calif. It also was greatly appreciated by the early navigators since, when it grows close to the shore, it is usually attached by holdfasts to large rocks so that mariners were many times saved from shipwreck by the danger signals formed by these large olive-brown floating seaweeds.

ALGAE AS FOOD

In the most primitive civilizations man is forced to seek from the vegetable kingdom sources of food, especially in times when animals are not plentiful. Since the earliest times, algae have been used by man as food, especially as condiments, and a number of civilized peoples still consume the seaweeds.

The Chinese and the Japanese doubtless use a greater quantity of seaweed as food than any other peoples, although the Hawaiians eat it in large amounts.

The beautiful livid purple gelatinous but firm membranaceous seaweed called *Porphyra*, which is cosmopolitan in its growth, is one of the most important food plants in Japan. It is consumed by every class of the Japanese people and the cultivation of *Porphyra* is one of Japan's leading industries. The Japanese call it amanori or laver (pl. 2, fig. 1). It grows abundantly in bays and near the mouths of rivers on all parts of the Japanese coast. Its cultivation was begun at a very early date in Japan, and its financial returns, considering the average yield per acre, are not surpassed by many branches of Japanese agriculture. The earliest and most celebrated *Porphyra*

grounds were in Tokyo Bay. One or two centuries ago, according to Smith (1904a), *Porphyra* grew in natural quantities at the mouth of the Sumidagawa, near Asakusa, in Tokyo. As the river carried down large amounts of gravel, its mouth advanced farther and farther into the sea, thus making the waters near Asakusa too fresh for its growth. To the dismay of the inhabitants *Porphyra* ceased to grow there. Then the cultivation of *Porphyra* was begun. The quality of the cultivated *Porphyra* is dependent largely on the weather. It is best after frequent rains and snowfalls have made the shallow water brackish.

Harvey tells us varieties of *Porphyra* are gathered in winter off the rocky shores of Europe. The British and French boil it for many hours until it forms a dark brown semifluid mass which is called marine sauce, sloke, slouk, or sloucawn. Lemon juice or vinegar is served with it and its flavor is more delectable than its appearance. At some of the British establishments for preserving fresh vegetables, it was in the past century put up in hermetically sealed cases for exportation and use at sea, or for use at seasons when it did not grow on the rocks. In winter, the *Porphyra* fronds grow abundantly on the rocky coasts of Europe and North America. *Porphyra* is not only regarded as antiscorbutic but is said to be useful in glandular swellings, possibly because of the minute quantity of iodine which it contains.

Harrington states that the Indians have used *Porphyra* for thousands of years, ever since they came from Siberia. It grows on the Gulf of Alaska and along the whole archipelago of Alaska as well as on the shores of Washington, Oregon, and California. Wherever it grows, the Indians would hunt for it.

The Indian does not believe in using salt on his food. The Iroquois referred to a white man as "a salty one" because they ate people and they knew that the white man had a saltier taste than the red man. The Indians would not salt their mush, or their eggs, as they believed that salt would make their hair turn gray and their toes turn up before their time. Salt was white man's style so it should be avoided, but sea lettuce, as they called laver, was native style, and therefore they gathered the sea lettuce with which they supplied the salt need of their bodies. The Indians collected the sea lettuce in the spring because their grandfathers were accustomed to gather it at that time.

The various kinds of kelp, coarse, broad-fronded members of the Laminariaceae family (pl. 3, fig. 1) form an important food product of Japan, and large amounts of the kelp or kombu, the name of the foods made from kelp, are exported from Japan to China. Kombu products have been sent to the East Indies and San Francisco but

there is very little sale for kelp as a food here where the dietary standards differ so radically from those of the Occident. It is valuable to Japan because of its cheapness and the number of ways in which it can be prepared as food. Most of the kelp is obtained from Hokkaido, the most northern of the main islands of the Japanese Archipelago. The kelps grow on all parts of the coast, but those of highest quality are found on the northeastern coast which is washed by the Arctic current.

Undoubtedly the most important seaweeds used as food and in industry are those with jelly-making properties that belong to the family *Gelidiaceae*. Agar is made chiefly from the algae *Gracilaria lichenoides*, *Gelidium corneum* (pl. 2, fig. 2) and other closely related species of *Gelidium*. The Chinese introduced it to Japan in A. D. 1662. It was used principally as a substitute for bird's-nest soup stock and as a summer jelly. It is used in Japan, China, and India as an ingredient of soups and sauces, and is also used as a sort of dessert and as a candy. In Japan it is called Kan-Ten which means "cold weather" as the substance made from the algae can only be manufactured during the winter months. The manufactured product is called agar.

In the early years of its use, or rather before the large agar industry was developed, the seaweed was merely boiled to form a mass of jelly, but at the present time the agar of commerce is in the form of sheets, sticks, bars, and flakes.

Kan-Ten is pearly white, shiny, transparent, tasteless, and odorless. It swells in cold water but does not dissolve, and is soluble in boiling water and easily forms a jelly. In foreign countries it is used chiefly where a gelatin is required such as in making jellies, soups, sauces, candies, pasteries, and many desserts, in all of which it is far superior to animal isinglass or gelatin. It is also used for the clarifying of wines, beers, coffee, and other drinks.

Agar is used to a great extent in the United States. It is very desirable in food manufacture as it jells rapidly and at relatively high temperatures without the assistance of intermediary substances. It has proved very economical because of its high gel strength. Experiments have shown tnat agar in bread and pastries, on account of its high moisture-retaining quality, keeps them fresh longer. The confectioner can use it to make a healthful jelly candy with less sugar by using agar in ¾ to 1 percent solutions. For that reason it is very economical. It provides a good body to drinks, and acts as a stabilizer in chocolate drinks and syrups, in which it prevents the forming of sediment. A manufacturer of ginger ale and fruit syrups believes that it sharpens the flavor. Agar has proved to be of great value commercially in the manufacture of sherbets, ice creams, and

cheeses. It imparts a smoother texture to the product and also acts as a stabilizer. It has been highly recommended by the manufacturers of mayonnaise, and Tressler (1923) states that it is superior to gelatin in preventing the disintegration of fish and meat products in cans, as the agar retains its gelling power to a greater extent than gelatin after subjection to the higher temperatures necessary in processing fish and meat foods. Many breakfast and health food manufacturers are incorporating agar in their products since although it has no food value in itself, it helps to modify highly concentrated diets and acts mechanically in a manner similar to the cellulose of vegetable foods, and consequently can be considered excellent roughage.

Japan has long been the world's greatest exporter of agar. But considering the large supply of the agar-forming seaweeds that grow on our own Pacific coast and the modern equipment in the factories here, which is far superior to that in Japan, where most of the preparation of the product is done by hand, there is no reason to fear that American manufacturers will be unable to supply all of our needs for this indispensable product.

Another seaweed that forms a nearly colorless, insipid jelly, and can be cooked with milk, seasoned with vanilla or fruit and thus rendered highly palatable, is *Chondrus crispus*, the carrageen or Irish moss of the markets. It is a nourishing form of diet for invalids and has been recommended in medical cases as will be seen later. It grows abundantly on the rocky coasts of Europe and on the shores of the northern States of America.

Chondrus crispus is a red seaweed of the family *Gigartinaceae*. (See pl. 3, fig. 2.) It is a perennial plant that reaches its full development in the spring and summer. The tufted plants vary from dark green to red in color and after drying are almost gray or white. The center of the industry in the United States is at Scituate, Mass. In 1939, 200,000 pounds of moss was "pulled" bringing in a total of about $20,000. Two and a half hours before low tide, the mosser puts on oilskin overalls and rubber boots and sets out in his dory, equipped with pulling rake and a bottle of cod-liver oil to smooth the water. The moss is bleached on the beach (pl. 4) where the successive stages in the process, deep purple, dark red, pink, light brown, and finally yellowish white, turn the shore into a gigantic patchwork quilt. The moss is washed in salt water, dried, packed in barrels, and shipped to the market.

Irish moss is best known as a preparation for delectable blanc manges. It is also used in confections as a filler, and to give body to candy. In ice cream it serves as a stabilizer and prevents melting, since by its use the consistency of the ice cream is only partially dependent on low temperatures.

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One of the most important uses of Irish moss before prohibition was in the "fining" of beers and ales. The cloudy solution of malt extract in the early stages of beer brewing contains insoluble and undesirable proteins which can be removed by a tedious process of settling or a swift process of "fining." The Irish moss is added to the brew while it is being boiled. The gelatin freed from the seaweed by boiling unites with the tanin of the hops to form a flocculent mass which encloses the suspended particles, the impurities, which are then removed as a scum. With the repeal of prohibition and the reopening of the beer industries, many manufacturers began to use chemical finings to fine their beers. The use of Irish moss is very economical as half a crateful of it is more than enough to clarify 500 barrels of beer. Irish moss may also be used in the fining of coffee, for which purpose it is more economical than eggs.

Algin, a mucilaginous product obtained from the kelps of the brown seaweed family, as described in more detail in the section on algae as cosmetics, is also extensively used in the food industry. Algin is nontoxic, possesses nutritive value, and is not an allergen. It is used primarily in foods as a stabilizer, chiefly in ice cream, where it prevents the formation of large ice crystals without masking the flavor and produces an ice cream that has a smooth, velvety texture of creamy consistency. It facilitates ice cream manufacture since ice creams made with algin whip fast and do not require any "aging" before freezing. It is of similar use in water ices and sherbets. It is used as a suspending agent for the cocoa fibers in chocolate milk, and in milk puddings it acts as a jellying agent. It is used as an emulsifying and stabilizing agent in place of starch and various gums in salad dressing. It is also found to be a valuable addition to doughnuts, cakes, icings, buttermilk, cream, and confectioneries, especially marshmallows.

The vegetable stabilizers, agar, algin, and Irish moss, notwithstanding their higher price, have been increasingly used in the manufacture of ice cream instead of animal gelatin. Their use has been stimulated by the objection of the orthodox Jews to the use of animal gelatin in the manufacture of ice cream as it is contrary to the ritual of orthodox Jewry to eat an animal product combined with a dairy product. To meet this objection, some manufacturers have completely abandoned the use of animal gelatin as a stabilizer in their products.

The dulse (Scotch) or dillsk (Irish), *Rhodymenia palmata*, is one of the red seaweeds with which Americans are familiar as it is often found in a rough-dried state in the water-front markets of Boston, New York, and other seaports of the United States. (See pl. 5, fig. 3.) In some places on the west of Ireland, this seaweed forms the chief relish to the Irishman's potatoes. Its use is not confined to the poor

alone since children are particularly fond of it. In the Mediterranean, it forms a common ingredient in soups. It is usually eaten raw or dried as a sort of salad or relish. In the olden days, it is said that some of the Scotch or Irish were addicted to chewing it before tobacco and chewing gum became popular.

It is natural that the peasants and the fishermen should use more varieties of seaweed as their food than do the better classes in Japan and China.

MacCaughey (1916) has written an interesting account of the importance of seaweed in the dietary of the Hawaiians. The ancient Hawaiians considered seaweeds a necessary staple of their daily food, and many present-day Hawaiians still consume it. The villages of Hawaii, like those of other parts of Polynesia, were usually situated near the seashore. The Hawaiians were a maritime people and very familiar with all the sea products, since the greater part of the population was habitually engaged in fishing. The protracted labor and hazard involved in the deep-sea fishing made it the work of the men, but the women and the children as well as the men enjoyed reef fishing. A wide variety of marine edibles including crabs, crayfish, shrimps, mollusks, holothurians, sea-urchins, octopi, and fish of many kinds were obtained from the lagoons and shallower waters. The native limu, the Hawaiian name for seaweed, formed an important element in these waters also. About 75 species of seaweed were used as food in this island world, and for each species the Hawaiians had a specific name. In fact, Hawaii is noted for having the largest variety of edible seaweeds in the world, although they are poor in quantity as compared with those of Japan and other parts of the world.

The seaweed was collected in various ways according to the nature of the habitat. Some species, such as *Sargassum* and *Gracilaria*, drift ashore in abundance and were easily gathered. Other kinds, growing in the quiet waters near the shore, such as *Ulva*, *Enteromorpha* and *Chondria* were readily collected by the older women and the children. Those seaweeds with stout stems and holdfasts, occupying the black lava rocks in rough waters where they were continually pounded by the surf, could only be collected by the experienced swimmers, the men and the younger women. They used a sharp stone or chisel to separate them from the rocks. *Gelidium* and *Porphyra* are of this type. Still another type including *Gymnogongrus* and *Dictyota*, grew on the outer edges of the reef where the heavy rollers break. These were usually gathered by the men in outrigger canoes. A few species, such as *Porphyra laucostica*, occur only in restricted localities or during brief seasons, thereby making them choice delicacies to be served only to the nobility, or

they were consumed only locally and not generally used by the entire population.

The Hawaiians anticipated by many centuries the more recently advocated plans of limnologists for cultivating economically aquatic vegetation. In the olden time, the Hawaiian nobility had the rare and choice varieties of limu transplanted to the vicinity of the chief's beach home where they were protected and easily available. The fish ponds were used frequently as algal gardens. The less desirable algae were weeded out and the semicultivated forms developed much more luxuriantly than they otherwise would have done. One of the ancient royal limu gardens is near the beach residence of ex-queen Liliuokalani at Honolulu.

With the advent of the white man on the island, the collecting of seaweeds was greatly facilitated by the glass-bottomed "water-boxes" and sharpened iron rods. The natives quickly observed their usefulness and adopted them. In ancient times, the limu gatherer had been compelled to rely on his vision alone and a simple stone chisel.

The women took charge of the seaweeds when they were brought ashore. The various kinds were sorted and then washed in salt water and fresh water. Certain species decayed rapidly when washed in fresh water, so they were rinsed in salt water and eaten immediately after preparation. After the other limu had been cleaned, it was salted, chopped or broken into small fragments, and eaten raw like a salad or relish. It was the universal accompaniment of the fish that formed the essential part of the native diet. At times of war or famine when the usual supply of vegetables, such as taro, sweet potatoes, or yams fell short, the limu was cooked in an underground oven with the meats.

Certain types of filamentous algae that grew in the mountain streams as well as some marine forms were subjected to a "ripening" process. This limu was soaked in fresh water for 24 hours or more, thus causing the partial decomposition of the seaweed and the development of a strong odor.

Finely chopped limu was eaten with raw fish, squid, shrimps, limpets, crabs, sea-urchins, holothurians, kukui nuts, and chili peppers. One of the favorite relishes was made by roasting kernels of the kukui nuts (*Aleurites moluccana*) or candlenut, chopping them fine, and then mixing them with limu and salt. This was kept for months in glass jars and was excellent with bread and butter as well as with cold meats. It resembled Russian caviar in flavor, and was served with poi, raw or cooked fish, or roast meats.

In modern times, in spite of the great shrinkage of the native population, limu forms a staple article of merchandise at the fish markets.

In Honolulu, the chief market in Hawaii, the annual sales for 1 year amounted to about 5,000 pounds, selling at about $2,500. This limu consisted of Kohu, *Asparagopsis sanfordiana*, limu ele-ele, *Enteromorpha* spp., and limu-o-olu, *Chondria tenuissima*. Hawaii's preponderant oriental population uses large quantities of the seaweed.

In the Philippines, especially in the northern provinces of Luzon, seaweeds are commonly boiled and mixed with vegetables. In the Bicol regions the algae belonging to the *Caulerpa* group, are used chiefly. In Ilocos, Cagayan, and La Union Provinces, the seaweeds are eaten raw as salads. The following are some of the edible varieties found in Ilocos and Cagayan Provinces: *Aganthopera orientales*, *Caulerpa racemosa* var. *uvifera*, *C. sertulariodis*, *C. Freycinnetti*, probably *C. peltata* but possibly a form of *C. chemnitzia*, *Chaetomorpha*, *Enteromorpha*, *Gracilaria*, *Hydroclathrus cancellatus*, *Hypnea* (near *H. nidifica*), and *Sargassum*.

Some of the edible varieties found in La Union Province are *Aghardiella* sp., *Fucus*, commonly found in Manila Bay, *Chaetomorpha crassa* (Ag.) Kutz, *Codium tenue* Kutz, *Enteromorpha intestinales*, *Eucheuma spinosum* (L.) J. Ag., *Gracilaria confervoides* L. Grev., *Gracilaria crassa* Harv., *Halmenia formosa* Harv., *Liagora cheuneana* Harv., and *Sargassum siliquosum*.

In Guam, the natives use some of the gelatinous forms for making blanc mange, according to Safford.

Some of the passerine birds use their saliva to glue together the feathers and twigs with which they build their nests. This habit points to the extraordinary ability of the sea swift *Callocalia* of the Far East which is able during its mating season to secrete enough saliva to form a nest of consolidated salivary juice. (See pl. 5, figs. 1, 2.) If the nest is destroyed in any way and has to be rebuilt by the sea swift, it usually weaves in bits of seaweed which led to the supposition by the early French scientists that the nests were made of jellylike seaweed. The nest is shaped like a shallow half of a small cup and is fixed against the walls of cliffs and caves by the seashore on the islands of the Indian Archipelago, especially in caves on the shore of Java. Some of them look like frosted sugar and consist principally of mucins. Over 3½ millon of them used to be sent from Borneo to China in 1 year as the Chinese connoisseurs in foods considered that they contained remarkable aphrodisiac qualities and would pay a king's ransom for them. They formed the stock for the famous bird's-nest soup of the Occident. When the nest is stolen or destroyed the swift makes a substitute nest of inferior quality, of a yellow color which is very obviously eked out with seaweed. The alga found most frequently in these nests is

Gracilaria spinosa, one of the jelly-forming algae. Occasionally, the layman confuses seaweed nests with the nests that are used for bird's-nest soups, but actually they are very different from each other.

"Can-can" is the peculiar dry and tangled egg mass of the volador or flying fish which is collected in season and dried so that it may be kept in the market throughout the year. This product has long been familiar to the natives of Peru. The egg mass is usually found entangled in the seaweed.

During World War I, peoples in Europe found it necessary to turn to seaweeds for a source of nourishment. According to Alsberg, there is no proof that seaweeds have more than a moderate food value although their value as an antiscorbutic, similar to cabbage and lettuce, is appreciated. Very little is known about the proteids of seaweeds, but according to Cameron, they do not begin to approach the food value found in cereals. The value of seaweeds as a food is to a large extent due to the mucilage produced by the membranes of the cellular tissue which is rich in pectins and hemicelluloses; it dissolves readily in boiling water and forms a jelly when cold. Because of this property of jellification, the attention of experts has been directed to the utilization of seaweeds both in cookery and in various commercial preparations.

Very little is known about the chemical composition of these membranes. Among the green seaweeds, the cellulose is associated with hemicellulose, a substance that is soluble in 3 percent sulfuric acid solution and contains a great abundance of xylane. There is also an insoluble portion rich in dextrane. Another hydrocarbon that has been detected in *Fucus* is called fucine. It is soluble in 1 percent sulfuric acid, turns blue with iodine, and is localized in the middle lamella. Dextrose and methylfurfurol occur in the brown algae. The red seaweeds, according to Perrot and Gatin, contain galactans, mannans, levulosans, dextrans, and sometimes methylpentosans. Some of these complex carbohydrates are a possible source of energy, but their extent is still unknown. Fat is a negligible quantity. The analyses given below show what little justification there is in arguing for the food value of algae.

TABLE 1.—*Analysis of Turrentine (Cameron)*

Gelidium corneum

	Percent
Water	22.29
Protein	6.85
Carbohydrates	60.32
Ash	3.81
Fiber	6.73

Laminaria spp.

	Percent
Water	22. 82–24. 44
Protein	5. 49– 5. 82
Fat	1. 52– 0. 74
Soluble nonnitrogenous material	47. 83–45. 57
Fiber	4. 55– 6. 44
Ash	18. 69–17. 00

Of other substances found in seaweeds, bromine occurs most abundantly in *Fucus serratus* (pl. 9, fig. 4). *Laminaria digitata* (pl. 6, fig. 1), L. *saccharina* (pl. 3, fig. 1), and *Fucus vesiculosus* (pl. 6, fig. 2) are richest in iodine, *Sacchoriza bulbosa* containing a little less. It is not yet known whether iodine is contained in the form of alkaline salts or in organic combinations.

The vitamin content of several algae used as food was tested recently by Norris, Simeon, and Williams. They found that *Alaria valida*, *Laminaria* sp., *Porphyra nereocystis*, *Porphyra perforata*, *Rhodymenia pertusa*, and *Ulva lactuca* were good sources of vitamin B, and compared favorably with many fruits and vegetables.

Porphyra was the richest source of both vitamin B and vitamin C among the algae tested. A number of algae from the different orders were found to be as rich a source of vitamin C as lemons. The algae growing on the littoral zone or on the surface tend to be higher in vitamin C than algae that are dredged from a depth of 5 to 10 fathoms.

The sugar, mannite, has been prepared from certain species of *Laminaria*. *Laminaria saccharina* (pl. 3, fig. 1) contains 12 to 15 percent of this sugar. In Kamchatka the natives prepare an alcoholic drink from dulse or *Rhodymenia palmata*.

ALGAE AS FOOD FOR DOMESTIC ANIMALS

On the northern shores of Europe, seaweeds have long furnished provender for cattle. So general was the use of seaweeds by the domestic animals that there was only one variety for which the cattle had a great distaste and would not touch as food, a certain variety of *Laminaria* which the Norwegians and Lapps called Neptune's belt because of its form similar to a long, broad ribbon, or the horse's kelp or sea devil. The ancient peoples in the Scandinavian countries thought that it must be bewitched since the cows would not touch it and they believed that it was employed by the sorcerers to excite the sea horses. *Rhodymenia palmata* (pl. 5, fig. 3) constitutes a favorite food of the Scandinavian goats, cows, and sheep. On certain small islands of Scotland, the cows and sheep go down to the shores at low tide to hunt for this alga, also for *Alaria esculenta* (pl. 6,

fig. 3). When *Rhodymenia palmata* grows attached to the stipes of *Laminaria cloustonii*, the sheep nibble at the *Rhodymenia* without touching its support. *Laminaria cloustonii* (pl. 8, fig. 2) sometimes grows in such abundance that it covers the other seaweeds. The cows raise it up on their muzzles and hunt below it for the seaweeds that they like. Only the fronds of *Laminaria flexicaulis* are eaten. The peasants gather it from the shore in large quantities to give to the beasts in the stable, and as it is considered a very healthy food it is given to them fresh from the beach without being washed in water. On the whole coast of Iceland in the winter, and even in certain places in the summer, thousands of sheep and other cattle wander freely and eat the seaweed even when there is grass available. In certain localities they are not given additional food, although in places some additional grain is supplied to them. On the coasts, as a rule, the cows do not go to pasture, but are given *Rhodymenia palmata* (pl. 5, fig. 3) and *Alaria esculenta* (pl. 6, fig. 3) in the stable since their milk does not absorb any taste from it. Their meat does not show any ill effects from the seaweed diet, although it is said that at Langarnes, where only seaweed is fed the animals, the lambs have weaker legs than those in the interior of the island.

Sometimes the Icelanders gather seaweeds to prepare as supplemental fodder. They wash it in water to remove the adhering sand, then bury it in deep ditches where it is pressed down under a layer of stones and thus compressed until it forms a firm mass which is cut into pieces with axes and fed to the animals in the winter. In certain places *Alaria* is gathered in the autumn, dried in the air after being washed with fresh water, and then packed in the barn alternately with layers of hay. The nutritive equivalent between the algae and the hay varies with the quality and digestive ability of the different species of plants and also with the animals. The sheep of the Iceland coast that have been nourished with seaweeds for several generations digest it more easily than the sheep of the interior which have been habituated to eating only hay and grain. The Norwegians often boil the seaweed with fresh water and then feed it to their beasts. There are two factories in Norway where the algae are dried and then broken into pieces, but because of the salts and the iodine present in the seaweeds, it is thought best not to feed them to the cattle in large quantities. De la Pylaie, who lived in 1824 on the Island of Sein, wrote that *Laminaria leptopoda* when it has been acted upon by the rain and the dew loses the olive-green color of the frond and becomes white like a piece of parchment. The cows would go to hunt for it at low tide on the coasts and would have nothing to do with it in its natural state but would eat it with great avidity when it had whitened.

The provender value of seaweeds was almost completely neglected in France until World War I caused a shortage of grain. A number of experiments were then carried on to determine the effect of seaweed as food for cows and horses. The experiments by Sauvageau (1920) show that *Fucus serratus* (pl. 9, fig. 4) and *Laminaria flexicaulis* even after a prolonged stay in their acidulated liquor form an excellent aliment for beasts. It was also found by Adrian that the seaweed food caused an augmentation of weight in the animals in proportion to the weight of algae consumed. The seaweeds seem to act as an accessory in the assimilation of the usual nutrients, an action that may be caused by the development of the digestive sugars, possibly by the multiplication of the hydrolizing bacteria, a study which Sauvageau (1920) believes should be made the subject of further search.

Experiments at Skjorn near Trondjhem, Norway, were begun in 1917 to establish the manufacture of cattle feed from seaweed. Meal was made from the varec or wrack, as the kelp is called, which was dried and ground into a fine powder. An analysis of this meal is given below:

	Percent
Water	6.49
Ash	19.07
Fat	2.77
Protein	7.04
Wood fiber	6.16
Carbohydrates	58.47

The protein was found to be digested in very small amounts, and the mineral content of the food was found to be too large. The seaweed meal was a useful addition to the hay for cattle feeding and proved to be excellent feed for hens.

A seaweed-meal factory was also started in Denmark where a process was used by which the seaweed is partially digested during manufacture. The washed plants are cooked with superheated steam, drained, and then pressed into cakes which are dried in a vacuum and ground into a coarse powder. The juice formed during cooking is evaporated until a portion of the salts crystallize. They are separated from the mother liquor in a centrifugal separator. The mother liquor is mixed with the powder and the mixture pressed into cakes. The analysis of this feed follows:

	Percent
Water	5.00
Protein (N×6.25)	13.12
Crude fiber	9.00
Ash	5.03

Albert and Krause investigated German seaweeds and stated that all kinds of German seaweeds were valuable for cattle feed. They

recommended that *Laminaria saccharina* (pl. 3, fig. 1), which they thought resembled spinach when cooked, should be used for cattle in times of scarcity of other foods.

Beckman carried on feeding experiments with dogs and hens giving these animals bread made from a mixture of finely ground seaweed, rye and potato flours. He said that during the baking the characteristic odor disappeared and that the bread was found to possess good properties.

Gloess wrote that algae from which the salts of potassium, bromine, and iodine have been removed can be used to replace oats in the diet of horses, and serve as feed for swine and poultry when mixed with their rations.

Intensive experimentation conducted by Ringen shows that the composition of seaweed varies with the season. The nutritive value is highest in the fall so that the seaweed intended for fodder should be harvested late in the summer. Two kinds of seaweed were used in his experiments: *Laminaria*, which was used to provide a product called Algit, and *Fucus* which was used to make Neptun. Seaweed meal is high in ash content and nitrogen-free extract. The calcium, magnesium, and iodine contents are especially high, but potassium, copper, iron, and manganese exist in quantities too small to be of any significance. The digestibility of seaweed meal is low, especially when it is made from *Fucus*. The digestibility is lower for pigs than it is for sheep. When meal prepared from *Fucus* is fed to the stock, there is a loss of 7 to 9 grams of digestible protein from the rest of the fodder. Sheep are able to use the protein in seaweed meal for maintenance and production of wool. Iodine in seaweed meal is easily absorbed, 55 to 58 percent of it being absorbed as compared with 35 to 40 percent in hay. The seaweed meal was decided to be a suitable calcium supplement to the grain ration of pigs. The nutritive value of seaweed meal is low. Pigs thrive better on Algin than they do on Neptun. The meal has no effect on bacon quality. Seaweed-meal feeding increases the weight of the thyroid and the iodine content rises both absolutely and relatively. The meal has no effect on the vitamin A content of pig liver. Seaweed meal has a strong laxative effect. Two sows that were fed seaweed meal during the period of gestation showed marked signs of iodism.

TABLE 2.—*Government typical analysis of kelp meal*[1]

	Percent
Ash (colloidal salts)	38.5
Carbohydrates	40.6
Protein	5.6
Fat (ether-soluble)	.4
Fiber	5.8
Moisture	9.1

[1] This analysis was obtained from the Department of Commerce, Washington, D. C.

The following minerals are included in the above analysis:

	Percent
Iodine	0.15
Iron	.13
Copper	.003
Manganese	.05
Phosphorus	.29
Calcium	1.28
Sulfur	1.04
Sodium	6.50
Potassium	12.49
Chlorine	13.67
Magnesium	.72

There are two commercial companies on the Pacific coast which utilize the tremendous groves of giant kelp that grow there to manufacture seaweed products (pl. 7), among which are seaweed meals used for poultry and cattle rations.

A meal manufactured by a firm in Los Angeles, Calif., is dried and ground kelp for use in animal feeds.

This meal has been tested for vitamins as shown in table 3.

TABLE 3.—*Results of vitamin tests on Kelco-Meal*

Vitamin A	3,000 international units per pound.
Vitamin B (thiamin chloride)	45 international units per pound.
Vitamin D	None.
Vitamin E	Trace.
Vitamin G (riboflavin)	3,500 micrograms per pound.
Vitamin F (filtrate factor [pantothenic acid]).	300 University of California units per pound.
Vitamin K	Present.

Of the above vitamins, vitamin G is present in sufficient quantity to be commercially important.

Owing to the vitamin G and mineral content, this meal can be used in combination with a protein source such as meat scraps or fish meal to supplant dried milk in various poultry and animal rations, thus freeing dried milk for more essential uses.

A concern in Los Angeles, Calif., leases from the State Bureau of Fisheries local kelp beds, which it harvests and dehydrates with a triple-drum air-drier originally designed to handle dehydrated alfalfa. For several years, it has manufactured a poultry feed, but recently they have also produced a cattle feed and a hog feed. These are all three supplementary feeds. In addition to machine-dehydrated kelp, the cattle feed contains ground dried fish, molasses, fish liver meal, and irradiated yeast. The hog feed also contains, in addition to the above, fish presswater concentrate, vitamin A, fish liver oil, ground oyster shell, sodium bicarbonate, nut charcoal, and anhydrous manganese sulfate. The poultry feed consists of machine

dehydrated kelp (ground), ground dried fish, fish liver, and fish presswater concentrate, fortified fish oils, ground oyster shell, sodium bicarbonate, and anhydrous manganese sulfate.

ALGAE AS MEDICINE

As was related in our introduction, one of the earliest uses of algae made by the Chinese and Japanese was as medicine. The monks used it in the olden days in cases of fever caused by the stomach. They would boil *Gelidium*, probably into a jelly, and sprinkle a little ginger and sugar over it. They would also make a milk paste of it and eat it with sugar and vinegar to protect themselves from disorders caused by the extreme heat.

Undoubtedly the algal product most used for medical purposes is agar which is the commercial name for the dried, bleached, gelatinous extract of certain red seaweeds belonging to the family Gelidiaceae (pl. 2, fig. 2). The name agar is an abreviation of the Malay term agar-agar which simply means jelly. In general, the jelly that comes from these seaweeds will absorb water and swell up but will only dissolve when heated to boiling. On cooling, the solution coagulates to form a more or less colorless, translucent jelly.

The effect of agar was recently tested by Nechales, Sapoznik, Arens, and Meyer on the motility of the stomach and the digestion of food in it. The experiments were performed on six normal subjects, on six patients afflicted with peptic ulcers, and on a dog carrying both gastric and duodenal cannulas. Agar decreased the emptying time of the stomach in each case.

Agar has also been successfully used when cooked with milk in the treatment of certain stomach disorders of young children.

The colloidal property of agar of absorbing and holding water and the fact that it is not digested makes it of great value in medicine as a laxative.

Tests made by Caravaggi and Manfredi have shown that agar contains principally laxative and purgative principals to the exclusion of deleterious secondary principles. They found that it has a slight nutritive value and maintains the tone of the gastrointestinal tract. They have reported methods for the extraction of the active principals of the drug in the form of a dry powder which may be compressed into pastilles with an inert filler. They state that these preparations act uniquely on the intestine by exciting peristalsis without affecting the functions of the stomach or the duodenum. They are painless in use and are not habit-forming.

As a laxative, according to the United States Dispensatory, agar may be administered cut up in small pieces and eaten like a cereal

with the addition of cream and sugar as desired. There is a chocolate-coated form of agar for those who do not care for it plain. It is also combined with mineral-oil emulsions in a number of medical preparations that are on the market. The dose prescribed for the dry agar is from 2 to 4 drachms (8 to 15 grams) administered once a day.

Agar was once used as a cure for obesity.

Glycerine suppositories have been made with agar as a vehicle, but they contain only 70 percent of glycerin as compared with 90 percent in those made with sodium sterate.

A preparation of agar is now used beneath bandages for healing wounds. This method of healing wounds dates back to the ancient Polynesians who used certain filamentous species of algae such as *Spirogyra* to make poultices for sore eyes. A number of kinds were also used by them as poultices for cuts, bruises, sores, and boils. The native Hawaiians also used an infusion of *Centroceros* as a cathartic, and *Hypnea nidifica* (pl. 8 fig. 1) was employed similarly for stomach troubles.

The most important use of agar in pathology and bacteriology is as a medium for the cultivation of pathogenic bacteria, of skin fungi, and of yeasts. In 1881, Koch developed the use of this medium for the isolation and cultivation of bacteria, and since that time agar has become an essential in every hospital and research laboratory in the world. Many scientists have worked on methods of preparation, filtration, sterilization, adjustment of reactions, its purification, and other details. Standardization of methods for its use in bacteriology and biology has been effected. Agar is used in standard methods for analyses of water, milk, soil, and sewage.

In his intensive report on hypercolloidal impression materials used in dentistry, Paffenbarger (1940) states that in the last few years in the United States many materials containing agar have been developed for dental use in making impressions. He states that probably the first scientist who used agar for taking impressions of living tissues was the Viennese investigator, Alphons Poller, who was granted a British patent on this material in 1925, and later an American patent. Dr. Poller called his compound negocoll. He sold the patent rights for the dental use of this material to the De Trey Brothers of Zurich, Switzerland, who manufactured a modification of it which they called dentocoll. Many materials of a similar nature have been developed in the United States since then, and most of them contain agar as the essential and important ingredient. The value of agar in these materials is that the sol or liquid state is reached only when the impression material is heated to practically the boiling point of water. When the liquid is formed, it does not

harden to a gel until it is cooled to temperatures that approach the temperature of the mouth. This means that there is a lag of from 60° to 70° C. (108°–126° F.) between the liquefying and hardening temperatures, which is important in dental materials of this type. The agar constitutent is doubtless responsible also for the unusual elastic behavior of the materials.

Irish moss, of which the scientific name is *Chondrus crispus* (pl. 3, fig. 2; pl. 4), also a member of the Florideae, the red seaweed family, forms a jelly very much like the agar-producing seaweeds. The commercial supplies of *Chondrus crispus* are obtained principally from Scituate, Mass., Nîmes, France, and Dublin, Ireland. Its Irish name carrageen comes from a place called Carragheen near Waterford, Ireland, where it abounds.

Chondrus crispus, or Irish moss, is nutritive, and being easily digested and not unpleasant to the taste, it forms a useful article of diet in cases in which the farinaceous preparations such as tapioca, sago, and barley are usually employed. It was formerly utilized as a demulcent in chronic pectoral affections, diarrhea, and irritations of the urinary tract, but it is rarely employed for those purposes today. The United States Pharmacopaeia recommends that it be macerated for about 10 minutes in cold water before cooking, in order to remove any unpleasant flavor it may have acquired from contact with foreign substances. The dose is 4 drachms (15.5 grams).

In 1835 Irish moss was a fashionable remedy for consumption. A former mayor of Boston, Dr. J. V. C. Smith, helped to establish the moss industry in Scituate, for at that time one person was paying from $1 to $2 a pound for Irish moss or carrageen, as the Irish called it, from Ireland. Today one drug company alone uses 6,000 to 7,000 pounds of Irish moss a year. This company sorts and cuts the moss with revolving knives, then packs the cured moss and sells it principally for invalid food or the preparation of blanc manges. Reputable physicians have recommended the jelly extract in cases of stomach ulcer.

Another company of manufacturing pharmacists puts on the market at least six distinct preparations of Irish moss. One is a laxative and regulator made up of Irish moss and mineral oil. The moss is used for its excellent emulsifying effect. Another is a cough medicine. The usual cough medicine consists of a soothing or quieting principle dissolved in a sirup of sugar, the body of which is necessary to hold the mixture against inflamed membranes. Since the sugar acts at times as an irritant, the cough medicine that uses Irish moss as a base is claimed to be superior. The Irish moss gives the medicine body and also produces a slight soothing effect in itself. The other preparations are described in the section of this paper entitled "Algae as Cosmetics."

Carrageen is still used in localities of Ireland for the treatment of pulmonary distress. Its jelly is also the acting principle in a poultice which consists of a piece of cotton filled with Irish moss jelly and then dried. It enters into the composition of a number of European pharmaceutical emulsions, in particular, the emulsion of cod-liver oil, which consists of 325 cc. of a 3-percent decoction of Irish moss, 500 cc. of oil, 500 cc. of sirup of tolu, and water sufficient to complete the liter.

Irish moss has also been used as veterinary medicine for nourishing cows, and has been found useful in rearing pigs and calves.

Algin, a product of kelp which is described in more detail in the section on algae as cosmetics, is of great value in the pharmaceutical field where its pronounced colloidal properties render it useful as an emulsifying, bodying, and suspending agent. Because of its superior qualities, it replaces tragacanth and other natural gums in the manufacture of greaseless lubricating jellies. It is a component of sulfanilimide ointment and other similar ointments. Iron alginate is used as a hematinic.

The United States Dispensatory lists *Gigartina mamillosa* as having chemical and medicinal properties that are probably identical with *Chondrus crispus.*

Helminal, according to the The United States Dispensatory, is an extract said to be derived from *Digenea simplex*, a red alga that grows on the eastern coasts of Asia. This plant is dried and sold by the Japanese and Chinese apothecaries. Its extract has been generally regarded as a valuable infantile remedy, but it is not as popular as formerly although it still is used in the provinces among the country people as a vermifuge. It is efficient in the treatment of *Ascaris* and *Oxyuris*. It is also nontoxic. It is sometimes sold in the form of tablets.

Until the end of the eighteenth century, two vermifuges of two calcareous algae, *Coralline officinalis* L. and *Coralline ruben* L. were popular as vermifuges. Their usage was discontinued when a Greek doctor named Stephanopoli discovered a small alga on the island of Corsica in 1775. He called this alga Corsican moss. This alga grew in red tufts on the rocks of Corsica when the sea was low and very calm. It was thought to be the same alga that was used as a vermifuge by the ancient Greeks. Corsican moss was in great demand as it effected a very rapid cure. The military hospitals used it with great success and it was long an article of commerce under the name of Corsican moss. The scientists had a great deal of difficulty in naming this alga. Kützing identified it as *Alsidium helminthochorton.*

In China, a mixture of algae including 1 *Enteromorpha*, 1 *Chordaria*, and 7 *Floridees* were used as a vermifuge so that it is not

surprising that the Chinese attribute vermifugal properties to marine algae in general.

At one time iodine, widely used in medicine, was derived from the seaweeds. In 1804 a French chemist named Bernard Courtois began work on nitrate of sodium, the process consisting of decomposing nitrate of calcium by the carbonate of sodium obtained from the burnt ashes of the seaweeds called kelp. In the course of his work, he observed that the iron vessels which he was using became corroded if the liquors from which the sodium salts had been crystallized were left in them for a long time. He found that these liquors when distilled with sulfuric acid liberated a body with a beautiful blue vapor. He examined this vapor and discovered some of its properties; for example, its formation of a detonating compound with ammonia. He gave a specimen of it to Clement who read a paper on it, but the rest of the investigation concerning it was carried on by Gay Lussac. Iodine was first employed as medicine by Coindet, of Geneva.

Iodine is a nonmetallic element which exists in certain marine algae particularly the kelps and rockweeds. These seaweeds are the largest of the algae that belong to the family Laminariaceae. The kelp industry for many years was an important one as well as a lucrative one in parts of England, Ireland, Northern France, Norway, and Denmark. It was engaged in by the peasants of the sea coasts who gathered the kelp by hand or by boat and burned it in covered trenches by the shore. After a time, the chemists found it cheaper to derive their iodine from the saltpeter beds of Chile and the great kelp industries of northern and western Europe began to decline. Brown seaweeds are still gathered for their iodine on the coasts of Japan, Scotland, Ireland, and Norway.

Iodine probably exists in seaweeds in the form of sodium iodide. Besides iodine, the ashes contain sodium carbonate, sodium chloride, potassium chloride, sodium sulfate, and other salts in small amounts. The deep sea *Fuci* contain the most iodine, and when these are burned at a low temperature for fuel as on the island of Guernsey, their ashes form more iodine than does ordinary kelp. In Japan, the seaweeds most used are *Ecklonia* (pl. 9, fig. 1) and *Sargassum* which contain about 0.14 percent of iodine. In France, species of *Fucus* are employed. The ash contains sometimes about 5 percent of iodine, but usually below 1 percent. During World War I, the United States began to utilize its vast groves of kelps, *Macrocystis* (pl. 7, fig. 1) and *Nereocystis* (pl. 9, fig. 2), which grow on the Pacific coast. The ash was burned to obtain potassium salts and iodine, but as soon as the war ended, the production of potash and iodine from kelp slowed down, as at the present prices for potash the utilization of kelp did not seem profitable.

The Japanese production of iodine and potassium iodide from kelp is still large. Okuda and Eto carried on a number of investigations regarding the iodine content of certain Japanese kelps. They found that algae in an open sea contain more iodine than the same species in an inland sea, and that the iodine content of the algae is lowest in the spring and highest in the fall.

The fact that goiter is unknown among the people of Japan and China is an indication of the effect of the iodine in their seaweed diet, while this deficiency disease is very prevalent among peoples of Switzerland who have no contact with the marine algae.

The charcoal derived from kelp was used at one time under the name of *Aethiops vegetabilis* or vegetable ethiops in the treatment of goiter and scrofulous swellings. Bladderwrack, the common name for *Fucus vesiculosus* (pl. 6, fig. 2), is an ingredient of certain nostrums used in the treatment of obesity. One scientist affirms that *Fucus vesiculosus* is largely used in Ireland for fattening pigs so it seems doubtful that its preparations are capable of reducing human obesity unless given in such doses as to interfere with digestion and injure the health. The possible explanation for its reducing power is found in experiments of Hunt and Seidell who present evidence indicating that the extract of this plant is a powerful stimulant to the thyroid gland.

The vegetarian food and diet shops have a number of commercial preparations made from algae, which they advertise for use in deficiency disturbances due to improper balance of minerals and especially the lack of iodine and calcium in the body. The majority of these products in powder and tablet form are prepared from the giant kelp, *Macrocystis pyrifera* (pl. 7, fig. 1).

ALGAE AS FERTILIZERS

Seaweeds have been used as fertilizers since the beginning of agriculture in Japan and China, and on the islands and coastal farms of northwestern Europe. The driftweeds were usually gathered after storms and piled on the shore or near the barns to dry out in time for the fall, when they were placed around the fruit trees and on the ground preparatory to planting the spring root crops. Even in the United States seaweeds, especially the kelps, were employed as fertilizers before the real reason for their action had been determined. The Rhode Island Agricultural Experiment Station issued a bulletin in 1893 stating that the value of seaweed fertilizers utilized was $65,044 as compared with $164,133 paid for commercial fertilizers. Since the founding of the colony at Rye Beach, N. H., the farmers have considered the success of their red clover growth due to the fact that they cover their land with seaweed and plow it under. On the island of

Nantucket off the coast of Massachusetts, the thrifty farmers still gather the driftweed and use it as fertilizer.

The fertilizing properties of the kelps are chiefly due to the potash or potassium salts contained in these seaweeds. If plants are to grow and thrive in the soil, the three essential elements necessary for their growth are potassium, nitrogen, and phosphorus. The seaweeds supply potassium in especial abundance. The application of seaweeds in bulk also has a desirable physical effect upon the soil. The majority of algae when first dried and then soaked in fresh water tend to swell enormously. When the dried seaweeds are plowed under into the light, dry soil, this spongelike action of the seaweeds holds small reservoirs of water in close contact with the roots of the cultivated plants. There is also a large amount of organic material in the kelp which decays slowly in the soil and forms humus.

There is a great deal of variation in the analyses made of kelp since the stipes of *Nereocystis* (pl. 9, fig. 2) and *Macrocystis* (pl. 7, fig. 1) contain much more potash than the leaves. The proportion of stipes to leaves in the samples of kelp according to Merz has a direct effect upon the result obtained.

Using figures obtained by Cameron, Frye and Rigg, Hoagland, and Turrentine, Rigg calculated the amount of potassium chloride, iodine, algin, and other contents in a ton of giant kelp. These figures given in table 4 indicate the large amount of kelp which must be handled in order to obtain a ton of potassium chloride.

TABLE 4.—*Content of a ton of the various kelps*

	Water	Potassium chloride	Other salts	Iodine	Algin	Crude fiber	Nitrogen
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Macrocystis luetkeana	1834	53.7	25.1–37.7	0.22	23 4	8.4	2.9
Macrocystis pyrifera	1736	52.5	26.7–55.7	.61	44.4	19.3	4.3
Alaria fistulosa	1726	39.3	27.6	Trace	(1)	(1)	7.1

[1] No data.

In 1912 Senate Document No. 190 appeared with a preface by the President of the United States and a letter of transmittal from the Secretary of Agriculture. This monumental book of about 300 pages contains a number of plates and maps describing particularly the larger Pacific coast seaweeds and kelps and reiterates that the seaweeds of the United States which have been neglected for so long a period should be developed agriculturally and economically. A second Government document entitled "Potash from Kelp," issued by the United States and Alaska, reports further surveys of the kelp beds of the United States and Alaska and reports progress in the mechanical problems connected with harvesting and drying kelp.

The reason for this increased interest in kelp was that the potash which the farmers of the United States used for fertilizer on their soil came almost exclusively from the mines in the Stassfurt region in Germany. This Stassfurt region was a former sea bottom where various soluble potassium salts accumulated in a solid form by the concentration and final drying-out of the sea water. Up to the beginning of World War I, the Stassfurt mines were the one important source of the potash supply of the world. The German conservation laws limited the amount of potash salts that were mined each year, also the amount of the annual product which was sold outside of Germany. The farmers of the United States were practically dependent upon Germany when they began to use artificial fertilizers. Previous to World War I, the United States was importing from Germany potash valued at 12 million dollars or more annually. For 3 or 4 years before the war broke out, there was disagreement between the American importers and the German Kali Syndikat over the raising of the price of potash and the threatened curtailment of the amount allowed to be shipped to the United States. This incident, together with the fact that the United States had undeveloped supplies of potash of its own, led the United States Congress to instruct the Bureau of Soils of the Department of Agriculture to make an investigation of the possibilities of developing within the boundaries of the United States a potash supply that would meet the domestic requirements and make the United States independent of any foreign nation in this regard.

The investigation included a search for potash in the alkaline basins of the arid West where the surface alkali includes potash salts and also in the feldspar and granite rocks which contain potassium in immense quantities but in the form of insoluble compounds. The Washington scientists finally took into consideration the long-established use of seaweeds as fertilizers for the soil and began a scientific investigation of the extensive groves of kelp on the Pacific coast to determine the amount of potassium salts contained in them.

Enormous kelp beds extend along most of the Pacific coast from Mexico to Alaska. The problem was to devise an economical means for harvesting the kelp and then converting it into fertilizer, potassium salts, and other valuable products.

About half the area of the kelp beds surveyed are in the vicinity of San Diego, Calif. Approximately two-thirds of the kelp that was cut grew near San Diego, and was used in industrial plants near that city. The amount of potash obtained from the kelp during Wold War I was slight as compared to the amount previously imported from Germany, but the kelp-potash industry was second only to the industry obtaining potash from natural mines. During 1917,

when there was a great shortage of potassium salts in the United States, 3,572 tons of potash (K_2O) was produced from kelp which represented only a small proportion of the harvestable kelp on the Pacific coast.

The cost of harvesting and drying kelp is high since kelp contains a large amount of water. The operation of the kelp-potash plants during World War I indicated that it was not possible to produce potash alone from kelp in successful competition with foreign potash. Only one privately owned plant operated during the war was designed for byproducts and that plant produced materials chiefly of value in wartimes. All commercial plants producing potash from kelp suspended operations immediately upon cessation of hostilities.

ALGAE AS COSMETICS

As we have already mentioned, the Roman ladies of ancient days used rouge extracted from *Fucus*. The young Kamchatkales mix the *Fucus* with fish oil to redden their faces. The ladies of several maritime regions in Europe used to macerate *Fucus* (pl. 6, fig. 2) in water and rub their cheeks with this mixture.

Technicians of a certain drug company noticed that the people who worked with Irish moss or *Chondrus crispus*, (pl. 3, fig. 2; pl. 4) preparing its mucilage as an emulsifier, never suffered from chapped skin on their hands even in the coldest weather. They quickly took advantage of this principle in making this seaweed the base of a popular preparation. Other ointments are also made from Irish moss. By using the gelatin of Irish moss as their base, a nongrease ointment results which it is possible to apply without fear of soiling the clothing.

Chilson (1938) recommends a pineapple juice hand lotion since he says that pineapple juice is an excellent hand cleanser in which a 3 percent mucilage of Irish moss forms 35 percent of the product. He also recommends Irish moss curling fluid for the hair. Its mucilage is the base for other curling fluids as for instance in sulfonated oil curling jelly. Irish moss is among the ingredients listed in the United States Government tooth-paste specifications for use as a binder. A thick mucilage of Irish moss is also used in deodorant pastes. Irish moss also forms an ingredient of compacts, powders, and rouges.

Agar, used as a binder in tooth pastes, may form 4 to 8 percent by weight of the tooth-paste materials.

The seaweed product which probably is used most in cosmetics is algin or sodium alginate. Algin was discovered by Stanford in 1884 although its manufacture in the United States did not begin

until World War I. Stanford was engaged in the Scotch kelp industry when he noticed that one of the brown kelps, *Laminaria digitata* (pl. 6, fig. 1) after exposure to rain assumed a tumid appearance and that sacs of fluid were formed from endosmosis of the water through the membrane, dissolving a peculiar glutinous principle. When the sacs were cut, a neutral, glairy, colorless fluid escaped. It could often be seen partially evaporated on the frond as a colorless jelly. This substance, insoluble in water, was given by him the name of algin. He found that algin contained calcium, magnesium, and sodium in combination with a new acid called alginic acid. When this natural liquid is evaporated to dryness, it becomes insoluble in water but very soluble in alkalies. This substance is so abundant in the seaweed that on maceration for 24 hours in sodium carbonate in the cold the seaweed plant is completely disintegrated. He found that it had an extraordinary gelling power. It has 14 times the viscosity of starch, and 37 times that of gum arabic. It does not coagulate with heat.

The commercial product is now in the form of a white powder produced from kelp found in Ireland, Scotland, Norway, France, and on the Pacific coast of the United States. *Laminaria hypoborea* is used for the production of algin in Ireland and Scotland, and *Macrocystis pyrifera* (pl. 7, fig. 1) is employed in the United States. Its English trade name is Manucol. Manucol solutions are stable in the pH range 5.5 to 8.5 and may be pasteurized at 50° C. without affecting the grade. It is useful for cosmetic preparations having an aqueous or glycerine base such as glycerine hand jellies, transparent setting lotions, shaving creams, and beauty milks. It is used in sunburn lotions and in hair creams and fixatives.

Its value in the cosmetic industry lies in the fact that sodium alginate produces standard mucilages that do not vary much providing the conditions of their preparation are similar. These mucilages are transparent, water white, and almost odorless, thus overcoming the difficulty caused by the use of certain Karaya gums which have a grayish-brown color and also avoiding the question of opacity which arises with the use of tragacanth. The viscosity of Manucol V solutions is raised enormously by the introduction of calcium ions and if sufficiently raised the solution gels. The thickening effect of calcium ions increases as the pH of the solution is lowered due to the precipitation of calcium alginate as a jelly from the soluble alginate. All metallic ions other than those of the alkalies, magnesium, and ammonium behave similarly. The interesting feature about alginates is that it is possible to vary the viscosity of the solution over an infinitely wide range merely by altering the proportion of the calcium or other ion.

The Algea Pradukter, a factory at Christiansund, Norway, was reported in the fall of 1940 to be experimenting with new uses of kelp, in particular with the manufacture of soap.

One company of the Pacific coast has a line of soaps, shampoos, soap pastes, and beauty lotions that it makes from kelp which they advertise as giving "good results in cold, warm, soft, hard, and salt water."

ALGAE AND TEXTILES

Since the earliest times, certain of the most succulent algae which have gluelike properties have been used by the Chinese and the Japanese for starching their clothes. The principal alga of this type is *Gloiopeltis coliformis*, although *Gloiopeltis intricata* is probably just as satisfactory. Various other algae such as *Chondrus crispus* (pl. 3, fig. 2), *Chondrus elatus*, and *Chondrus ocellatus* (pl. 9, fig. 3) are also employed for this purpose, although they do not make as fine a product. The Japanese call these algae funori, a word which means material for stiffening fabrics. The manufacture of funori is an important industry in Japan, although it does not rank with the agar and kelp industries.

In 1875 and 1876 the Société Industrielle de Rouen instructed three of its members, Clouet, Heilman, and Reber to study the possible industrial applications of the substance called hai-thao or thao, actually agar, which was imported from China and Japan. Attempts made by a silk manufacturer at Lyon to prepare silk tissues with the thao had given good results, therefore the Rouen officials desired information in regard to its use with cotton and linen goods. Heilman recommended that agar be used especially for fine tissues where suppleness is more desired than weight and stiffness. Heilman tried the comparative effects of Senegal gum, tragacanth, *Chondrus crispus* or Irish moss, and agar. He found that the Senegal gum gave the cloth a rough, dry touch. Tragacanth made the cloth a little more supple and almost as supple as the cloth sized with agar. The chief advantage of the agar was that it strengthened and compressed the cloth while tragacanth left it shallow and without any body. *Chondrus crispus* or Irish moss employed at a concentration of 3 percent gave the cloth a rich and "unctuous" touch which had no analogy with the cloth sized with agar. He recommended it for use in the silk stuffs. Heilman thought that agar would have a great industrial future in the sizing of calicos when it had been sufficiently improved.

The seaweed products that are now used in the preparation of sizes are Irish moss, funori, agar, and algin. Agar is too expensive and too valuable a product elsewhere to be used in the sizing of any but the most expensive fabrics such as silk. The amount of salt in

Irish moss sometimes gives a harsh feeling to thread, provided all the salt has not been removed from the moss by a preliminary steeping in water. Irish moss is used to thicken dye solutions for use in printing calico. A process of treating Irish moss extract with formaldehyde in order to make the dried size insoluble has been patented. Algin has been used for fixing mordants and is a substitute for various salts formerly used in fixing mordants previous to the dyeing of cottons and yarns.

Algin or sodium alginate is a very useful alginate since it is easily soluble in water and can be readily changed into soluble substances. For this reason it is valuable as a sizing substance. It is superior to starch in this use as it fills the cloth better, is tougher, more elastic and, since its solutions are very viscous, it goes farther than starch or any gum. As soon as the sodium alginate has impregnated the cloth it may easily be made insoluble by treatments with dilute acids, lime water, salts of calcium, barium, and various other metals. It can be used as a fixer for mordants in fabrics and to some extent as a mordant. Ammoniated aluminium alginate can be used for the preparation of waterproof fabrics since it becomes insoluble after drying.

In November 1938 the Department of Commerce received the notice of a new mucilage product made from *Chondrus crispus*, *Chondrus elatus*, *Gigartina tenella*, *Grateloupia filicina*, *Grateloupia flabellata*, *Hypnea seticulosa*, and other seaweeds. The mucilage from them is high in adhesive content and low in price. The mucilage is produced by washing the seaweed in fresh water, removing the salt, adding a definite quantity of water, and the effecting of certain physical and chemical treatments, the details of which are not divulged. The solution is made highly viscous and its solidifying property is reduced. The product is said to be high in solubility and a concentrated solution of more than 30 percent can be produced. The invention is significant in view of the appreciable imports of mucilage from abroad. Its use is very extensive in the special processing of textiles, for stickers in general, for the production of printing materials, and other uses.

In ancient times the seaweeds were used in dyes. There were certain ones that had the reputation of clearing the colors and making them more brilliant and intense, especially those that were used as red dyes. The ancients used *Fucus* which they called "red fucus" or "dyer's fucus" to dye their draperies and other linen materials.

By nitrating alginic acid, Nettlefold prepared a brown dye that is suitable for dyeing unmordanted cotton. This unmordanted cotton dyed a fine Bismarck brown color which was more fast to soap than many alkaline colors, equaling chrysoidine. The depth of the

shade was considerable and could be worked to a great intensity. In an acid solution the dye would not become attached to the fiber. Ammonia was the best alkali to use for this purpose. The brown dye had little power of attraction for wool. Mordanting did not increase the depth of the dye.

Some species of algae are used to make string. *Chorda filum* is very abundant on the French coast where it is used for that purpose. Plants of *Chorda filum* are often 5 to 6 meters in length. A series of them are strung together, two or three at a time according to the usage for which they are to be employed. They must be dampened when used as then they are stronger and less likely to break.

For centuries, the fishermen of Alaska have used the stipe of *Nereocystis* (pl. 9, fig. 2) which is long and flexible and the size of an ordinary window cord. They cut it below the pneumatocyst, soak it in a stream of running water until it is almost white, then stretch it, rub it to reduce it to the size desired, and then dry it in the smoke of their dwellings. This type of cord is easily broken when dried but extremely resistant when wet and much stronger than fishlines of linen or cotton. The pieces of the stipe varying from 10 to 15 brasses in length are knotted together to form a line 80 brasses in length, the size required for fishing at the entrance to the Strait of San Juan de Fuca, or of 200 brasses in length for fishing the black cod off the Island of Queen Charlotte in British Columbia.

When the kelp in long streamers, with its big floaters which the Alaskans call heads or bulbs, washes ashore on the beach of Juneau, the children cut the ropelike thallus and use it to make swings and jumping ropes as long as it is wet and humid. When it dries it stiffens and would be of no further use to them unless they greased it with some of the grease which is always present in the Indian dwelling, in order to make it pliable.

ALGAE AND CERAMICS

The first commercial use that the Chinese ever made of agar was for wrapping porcelains and bronzes which they sent to Europe.

The ancients have always searched for alkalies to employ in the manufacture of glass and pottery. It was not, however, until the seventeenth century that we find mentioned the use of seaweeds or the kelps in the manufacture of soda for the glazier's trade in Europe. Carbonate of soda does not exist completely formed in the seaweeds but is combined with fixed acid minerals and with organic acids that by incineration give carbonate of soda. The ashes of the sea kelps contain potassium salts mixed with sodium salts in relative proportions that differ with the various species. The term "soude" or soda

was given to the ashes of the burnt kelp in France because of its resemblance to the commercial product and its method of manufacture.

In 1692 Louis XIV gave to the Royal Company of Glass Manufacturers at Paris the sole privilege of cutting from March 15 to September 15 of each year for 20 years all the kelp along the coast of La Hogue for the production of kelp ashes, and allowed them to transport these kelp ashes to Paris. This law was revoked in 1718 by demand of the Normans who wished the kelp for fertilizers and to burn for iodine. In the glassworks all the ashes were used, since the portion of fixed alkali which was already in combination with the organic matter was in a state that acted as a melter for the other clays and sands which entered into the composition of glassware. For this reason kelp ashes were used with great success and to great advantage in the glass and porcelain works where common glassware was manufactured, especially in Normandy.

Funori or seaweed glue is used in the decorating of porcelains in Japan.

Algin is used as a binder and plasticizer in ceramics.

Mertle writes that Irish moss has been suggested as a substitute for fish glue in the preparation of bichromated enamel, but it has never been popular owing to the greater uniformity of results obtained with glue mixtures.

About 25,000 pounds of Irish moss is used each year by the paint industry in the making of cold-water or casein paints. Irish moss is used as a stabilizer to give the casein coloring matter and water consistency, and to hold the film in place while the casein hardens. Casein paints treated with Irish moss brush well and hold to the surface while they dry. *Chondrus crispus* is used in preference to other gums because of its cheapness, its thick consistency in extremely low concentrations, and its transparency, which keeps it from interfering with the color of the paint. Agar has been substituted for fish glue in process enamels to a slight extent.

Algin is used as a suspending, emulsifying, and bodying agent in water paints, resin emulsion paints, and other special types of paints.

ALGAE AND TANNING

In the early part of the nineteenth century the French gold beaters used supple gold-beater's skins to reduce the gold into thin leaves. Isinglass or fish glue was used to give the luster which the tanning removed. The animal substances cracked under the repeated blows of the wooden hammers. A Parisian manufacturer replaced the isinglass by agar and found he achieved better results. Irish moss or *Chondrus crispus* is used in the tanning industry, as it imparts to certain types of leather a gloss and a stiffness that is very desirable.

Its principal use is in the finishing of straight grains and grain upper leathers. When hides are split, the hair side is the grain side, a somewhat rough leather of a very even quality. The remainder of the split hide is uneven both in thickness and texture and finds its principal use in the manufacture of inner soles. After tanning is completed, the leather may be given one of several finishing processes, one of which includes the use of Irish moss. The gelatin is extracted from cured seaweed and then filtered for purification. This gelatin is swabbed onto the leather with brushes, thereby giving it body and stiffness. The leather is still dull in this state and must be glazed to give it a polish, which is accomplished by rubbing it with glass cylinders. Repeated glazing or the application of dressing materials then intensifies the luster to a gloss. Irish moss gelatin is used in shoe polishes, in which form it restores the finishes on worn, scuffed leather. The dull finish given to the leather at the factory is produced by revolving brushes on leather that has been treated with Irish moss.

The polishing effect of Irish moss is due to the ability of the mucilage to smooth and hold down the tiny, rough projections on the surface of unfinished leather. In this way grain leather is given the luster which we see on our own shoes. Luster is not as important as other qualities in the case of the inner soles, where Irish moss is used as a filler to impart stiffness and body to the leather. The gelatin of Irish moss is also used to impart body and luster and to assist in the waterproofing of the very heavy retan leather used in the soles and uppers of heavy footwear. One shoe manufacturer in New England imports from Ireland about 12,000 pounds of *Chondrus crispus* a year.

Agar and algin are also used in the treatment of leather.

ALGAE AND THE PAPER INDUSTRY

The Chinese in the olden days spread a little agar lightly over rice paper to make it more durable. They also mixed it with lacquer to strengthen paper, especially in the manufacture of fans and umbrellas. Agar is used now to some extent in the manufacture of paper as a paper coating, to impart resistance to penetration of resin, wax, and grease.

At various times processes of manufacturing paper from the giant kelps have been proposed but apparently with no commercial success. The cellulose obtained from the Laminariaceae bleaches easily and under pressure becomes very hard so that it can be easily turned and polished. A good tough paper can be made from it.

When dry, alginic acid assumes a hard, hornlike form that is very insoluble and resistant to the action of chemicals. It may be used for a substitute for horn and as an insulating material.

ALGAE AND PHOTOGRAPHY

In 1882 Mitchell proposed the substitution of agar for gelatin in the preparation of photographic materials needed in tropical countries. Several patents were obtained for this purpose. Manipulative difficulties and inconsistent results prevented photographic manufacturers from placing agar products on the market to any great extent, although a few firms in Germany and England were manufacturing agar papers some years ago. Cooper and Nuttall experimented further on the application of agar to photography. An agar film need be but one-eighth as thick as a gelatin film. Other advantages are that agar as compared with gelatin is cheaper and is more insoluble in water except when it is very hot. One firm states that as a reagent in sensitized emulsions, agar has proved to be of better quality than any similar material now on the market. In photomechanics the term "colloid" is applied to all substances that are capable of being rendered insoluble in water when impregnated with bichromates and exposed to the action of light. For this reason, agar and Irish moss are among the colloidal materials that are of value in the various phases of photomechanical plate making for the production of photographic images.

ALGAE AND WAR MATERIALS

During World War I, the Germans made a surprising use of a variety of *Laminaria*. When dry, the kelps with their massive thalli diminish in volume and become wrinkled. As soon as they are placed in water, they absorb the water, swell up, and return to their natural form. Some of the German grenades that fell into bodies of water or humid places, exploded after a certain length of time. When similar grenades were studied, they were found to contain sulfuric acid in a small glass ampoule and potassium chlorate. The grenades were hermetically closed with a piece of *Laminaria cloustonii* bearing at its internal end a sharp metallic point. With humidity the piece of seaweed elongated so that it pushed the metallic point against the ampoule, thus breaking it. The contact of the released acid and the chlorate caused an explosion. In other grenades the needle pushed by the piece of seaweed came in contact with a capsule of fulminate.

Algin is used as a binder in cartridge primers here in the United States.

ALGAE AND OTHER INDUSTRIES

In connection with national defense work, the algin products made by a company on the Pacific coast are supplementing the foreign gums such as tragacanth, locust bean, gum arabic, and other gums which are practically nonavailable since the present war started.

Algin has been found to be equal to, or better than, the foreign gums in most of the industrial applications that require the use of gums. The usage of gums is more widespread than is generally known.

Algin products are employed in the treatment of boiler water and other industrial waters, in can-sealing compounds, in oil-well drilling muds to seal off porous formations and resist the flocculating action of brines, and as a medium for separating battery plates in the manufacture of batteries.

For resolving and preventing the incrustations of boilers, sodium alginate is recognized by experts as one of the best preparations, as it precipitates the lime salts in a state in which they can be readily blown off. The charcoal formed during the manufacture of iodine by the wet process, when combined with algin, has been largely used for covering boilers under the name of carbon cement. Three percent of algin is sufficient to make the carbon adhere, and a cool, light, and adequate covering is formed. Agar is used as a suspending agent in a wire-drawing lubricant.

Just recently, a patent was given for the use of shredded agar to retard evaporation in tobacco.

Sharp found that agar activates nicotine in insecticide sprays to a noteworthy degree.

Certain species of seaweeds are used in different parts of the world for making ornaments and curios. Species of *Laminaria* having a hollow stipe are used for knife handles, since these kelps dry to a very hard, hornlike substance. They are called artificial staghorn.

THE PRESENT STATUS OF THE SEAWEED INDUSTRIES

In the summer of 1941, as this paper is being written, it is difficult to obtain recent figures from Europe and Asia regarding exports and imports of seaweed material. The few figures given below, however, give a slight indication of the importance of seaweed as an article of commerce.

AGAR

Japan has long been the world's leading producer of agar and is the only country that exports this product to any great extent. Only small quantities of an inferior grade of agar are reported to have been produced in China and the Soviet Union. In 1938 the Netherlands Indies developed a small industry supplemented by a second establishment opened by a well-known ice-manufacturing concern. The seaweed needed by these concerns is obtained along the Java and Celebes coasts, whence comes much of the seaweed used in the Japanese manufacture of agar. The seaweed could be purchased from the natives for as little as $1.65 per picul of 136 pounds. Suffi-

cient raw material is obtained in 1 picul for the manufacture of 1½ bales of agar with approximately 4,000 pieces to the bale. In 1939 the industry was still insufficient to meet domestic requirements but the two factories in operation hoped eventually to produce a surplus for export. The Japanese output of agar fluctuated only slightly from 3 million pounds annually during the period 1923–31. It then rose from 3.3 million pounds in 1932 to 5.5 million pounds in 1937, when the output was valued at about $2,800,000.

For the year ending June 30, 1938, Japanese production of agar was estimated at about 750,000 pounds less than in the preceding year, although the quality was better. For 1938–39 the yield was still lower, and even lower yet for 1939–40. The sudden reduction in 1938 was due to the stormy weather of the previous summer, which resulted in extensive damage to the seaweeds. The Japanese also attributed the lower yield to difficulty in obtaining sufficient labor to harvest and dry the seaweed and, later, to bleach the crop.

The principal primary markets for imported agar in the United States are New York, Indianapolis, and Detroit, where it is inspected, cleaned, and repacked for distribution by manufacturers of pharmaceutical and biological products. One food-supply house in Los Angeles used 43,000 pounds of agar in 1938.

The limit to which agar has been imported into the United States has been in the past governed only by Japan's ability to supply this product. Normally, Japan was able to supply agar in sufficient amounts to meet world requirements at reasonable prices. The prices have varied from year to year; within the past 2 years the prices have risen to record levels owing to a scarcity of supplies in Japan. During the first 9 months of 1939, the United States imported 377,355 pounds of agar valued at $266,331. Since the outbreak of hostilities in Europe in September 1939, the United States has imported a total of 54,898 pounds valued at $46,233. It is very likely that the shipments making up this total were cleared from Japan early in August 1939.

The war in Europe has had little effect upon the wholesale prices of agar in the United States. Prices prior to the hostilities had risen to high levels, owing to the scarcity of supplies already mentioned, thereby probably forestalling further advances in prices. Except for the Netherlands Indies there is little prospect of American importers being able to obtain agar from other countries of the world in the near future. During the first 9 months of 1939, Japan supplied all the agar imported into the United States except 40 pounds which came from China. Since the war began, Japan has continued sending agar to Germany by the Trans-Siberian Railway. It is interesting to note that Germany was the largest single purchaser of Jap-

anese agar in 1938. Germany imported about 20 percent of the total amount exported to all countries.

The domestic output of agar since production in 1923 has been very irregular. (See table 5.) Since 1932 practically the entire domestic output has been sold during the year in which it was produced. The principal markets are New York, Chicago, and other large cities. In 1938 production totaled 7,170 pounds, and sales were 6,820 pounds valued at $9,131.

Table 5 gives the figures for United States agar production from 1923 to 1938 and the first 9 months of 1938 and 1939. These figures were compiled by the Tariff Commission from data obtained from the sole producer prior to 1934, and subsequently from another producer who granted permission to publish his output.

TABLE 5.—*Agar: United States Production, 1923 to 1938, and first 9 months of 1938 and 1939*

Year	Quantity	Year	Quantity
	Pounds		*Pounds*
1923	7,755	1932	10,009
1924	7,281	1933	41,557
1925	117,773	1934	1,802
1926	29,877	1935	8,061
1927		1936	(1)
1928	22,797	1937	21,208
1929	5,140	1938	7,170
1930	44,895	1938 (Jan.–Sept.)[2]	5,288
1931	28,395	1939 (Jan.–Sept.)[2]	8,098

[1] Not available.
[2] Preliminary.

Briefly, the principal uses of agar are as follows: As an ingredient of glue and various adhesive preparations; a substitute for gelatin; culture media in bacteriological and scientific work; in foods as sausage casing, substitute for white of egg, a thickening agent in cream, milk, ice cream, sherbets, cheeses, cakes, puddings, sauces, soups, jellies, fruits, preserves, and in candies; as a suspending agent in wire-drawing lubricant; a substitute for isinglass; a preparation used beneath the bandage for healing wounds; a laxative; an ingredient of greaseless creams, ointments, and lotions; in dental plate impressions; as a reagent in sensitized emulsions; to size paper and silk; and as a thickener in drying and printing of fabrics.

KELP

The Japanese production of kombu or kelp probably exceeds that of any other country, reaching nearly half a billion pounds in 1929. The greater part of this kombu or kelp is used as foodstuffs. The annual production of kombu apparently varies considerably from year to year, probably depending on the effects of the ocean currents.

Japanese exports of whole, sliced, and powdered kelp for 1932 were valued at 2,013,000 yen. The export prices are usually lower than the domestic wholesale prices because export prices are generally quoted in larger quantities than in the case of domestic wholesale transactions. The kelp produced for China is of lower quality as a rule than that consumed in Japan. The kelp shipped to Hawaii and the United States is in meal and powdered form to be used as poultry feed, human food, and for medical purposes.

Norway produces kelp ash, the greater part of which is taken over by the iodine trust in Scotland. Ash is also exported from Norway to Great Britain. Before 1930 Russia was a fairly good market for the limited production of iodine, but the beginning of the manufacture of iodine in Russia adversely affected the Norwegian kelp burners. In 1932 heavy storms washed ashore large quantities of seaweed all along the northern and southern coasts of Stavanger. The kelp was of better quality than that gathered in previous years, and for it the burners would have been paid a higher price. However, a heavy decrease in price was caused at that time by the fact that Chile, the world's largest exporters of iodine, abandoned the gold standard, and with abundant stocks of iodine on hand, was able to cut the price about 25 percent. It was then impossible for manufacturers in England and Scotland to produce iodine from Norwegian or Irish seaweed ash at competitive prices. Lower price quotations for iodine were also reported from Japan and Russia.

Kelp was formerly exported from the Wieringen district in Holland in the amount of 2,000 to 3,000 tons annually, going principally to Belgium, England, and France, with occasional shipments to the United States. It consisted chiefly of fully prepared seaweed to be used as filling for mattresses and upholstery and for plant gelatins.

A firm in San Pedro, Calif., leases the kelp beds in the vicinity from the State Bureau of Fisheries and prepares the seaweed for livestock and poultry concentrates. This company also prepares kelp for human consumption.

A concern in Seattle, Wash., manufactures chiefly cosmetic products from kelp.

At one time there was a kelp-gathering project in Nova Scotia which obtained kelp from the shores of Nova Scotia near Clark Harbor and processed it in a plant at Rockland, Me. The fishermen were paid $3.00 a ton for kelp. They pulled it off the rocks by hand or with hooks and loaded it in their dories to take to the plant, where it was treated with chemicals in cement tanks to prevent it from rotting. It was then packed in rope bags, and when a sufficient quantity, 100 to 110 tons, had accumulated, it was shipped to Rockland in a power boat. In 1938, the first year of operation, 6 ship-

ments of kelp were made to Rockland, and in 1939 there were 5 shipments. No further details have been received from the factory since that time.

The Fisheries Research Board of Canada in the summer of 1941 reports that considerable quantities of kelp are harvested along the south shore between Yarmouth and Cape Sable Island and transported to Maine.

ALGIN OR SODIUM ALGINATE

The imports of algin into the United States are relatively unimportant, ranging in the New York district from 5,000 pounds to about 13,000 pounds during the years 1932 to 1935, inclusive. The United Kingdom was the principal supplier in 1933 and 1934, the Irish Free State in 1932, and Norway in 1935. Some sodium alginate materials enter as crude or semimanufactured seaweeds, algin, or extract of seaweed.

In the United States, sodium alginate has been produced by only one large company in recent years. The imports are relatively unimportant in comparison with domestic production. There are no available statistics of the exports but it is believed that they are small, if any.

The one company producing sodium alginate in the United States, located at San Diego, Calif., started operations several years ago by taking over a plant established in 1926 which had failed. After intensive research and developmental work, they have brought their product to a point of commercial production.

IRISH MOSS

The center of the Irish moss or *Chondrus crispus* industry is at Scituate, Mass., where an annual supply of approximately 200,000 pounds is produced.

Summarizing briefly, the gelatin from *Chondrus crispus*, is used in tanning, in fining beverages, as a filler and stabilizer in various foods, as a basis of certain drugs, and in the cosmetics industry.

CONCLUSION

A third verse should be added today to Longfellow's famous poem "Seaweed":

> When descends on the Atlantic
> The gigantic
> Storm wind of the equinox
> Landward in his wrath he scourges
> the toiling surges,
> Laden with sea-weed from the rocks.

Ever drifting, drifting, drifting,
On the shifting
Currents of the restless main,
Till in sheltered caves and reaches
of sandy beaches,
All have found repose again.

Indeed the seaweeds are not finding repose in this generation, for day by day the scientists and industrial workers are developing new uses for them in every walk of life.

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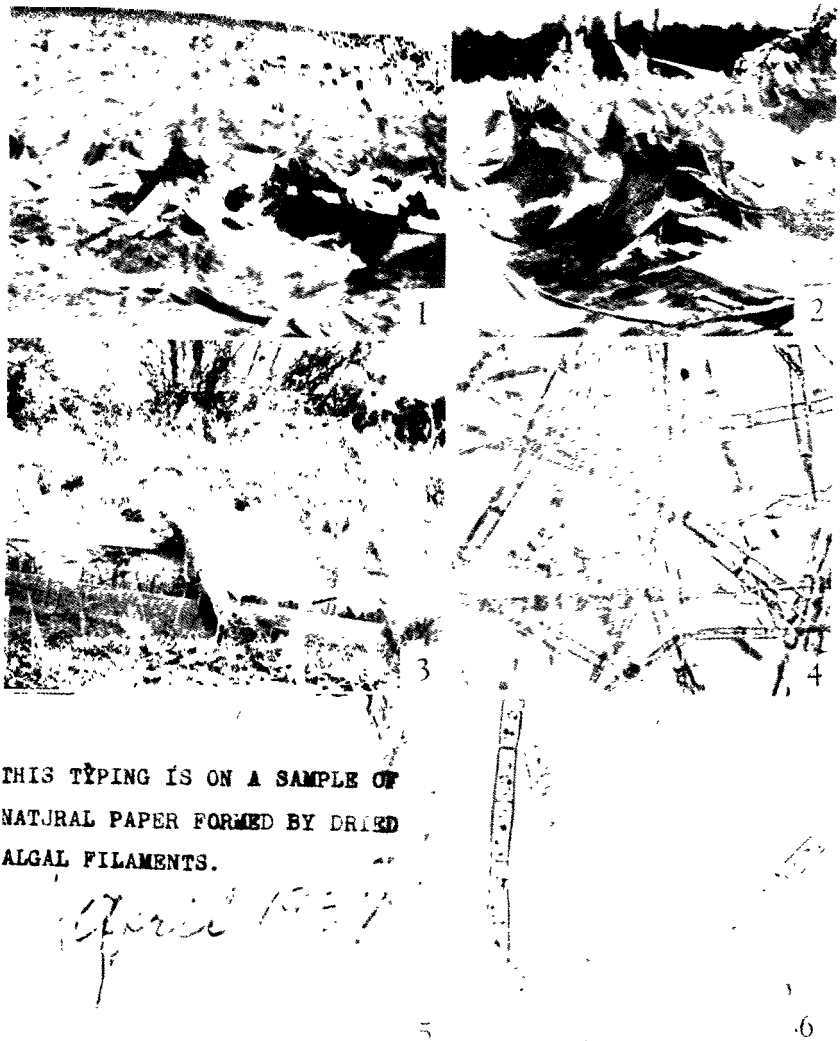
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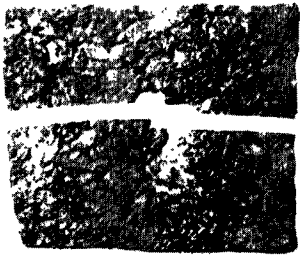


1–3, Views of field and fence showing old cotton stalks and fence covered with "natural paper"; 4, photomicrograph of a piece of bleached algal film with the filaments teased apart. 5, photograph of typing and lead pencil writing on algal paper. 6, photomicrograph of a few filaments of *Tribonema* from the green end of an algal film. Courtesy of C. F. Moreland









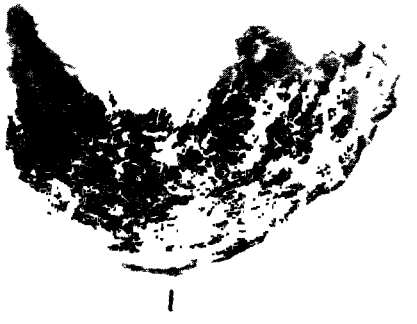
1, *Porphyra vulgaris* Ag., laver, 2, *Gelidium corneum* Lamour from Hong Kong, 3, *Porphyra laciniata* Ag; 4, a cake of *Porphyra laciniata* Ag. from Alaska. It forms an article of barter between the natives of the coast and the inland.



1, *Laminaria saccharina* var. Kutz from Japan; 2, *Chondrus crispus* Lyngh., from Cape Ann, Mass.



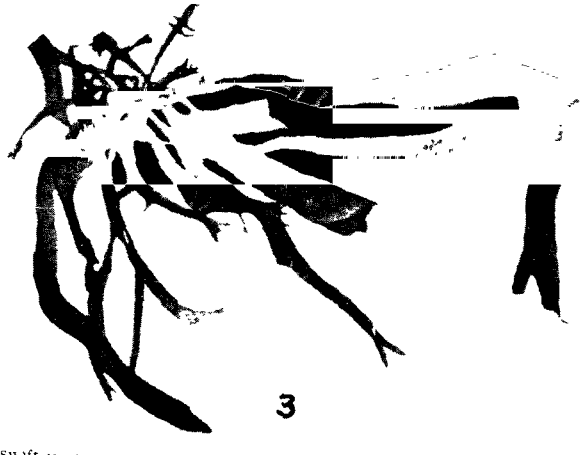
Drying Irish moss on the beach at Scituate, Mass. Courtesy of F. A. Conroy.



1



2



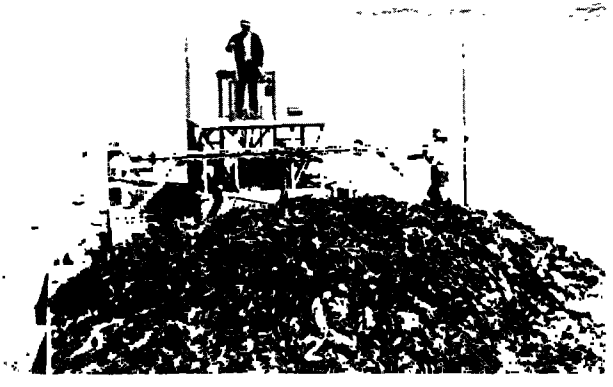
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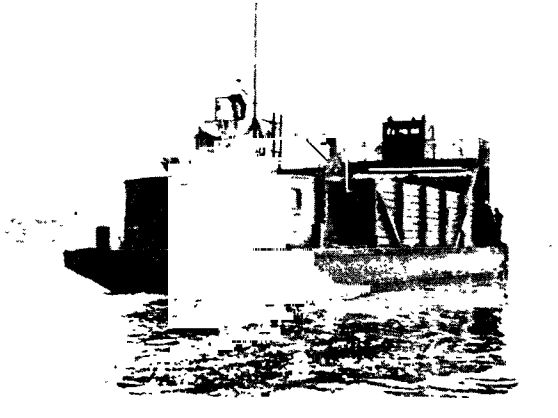
1, Nest of the sea swift in its natural state. 2, nest of the sea swift that has been cleaned preparatory to making bird's nest soup. 3, *Rhodymenia palmata mollis* ♂ and ♀, from the Aleutian Islands



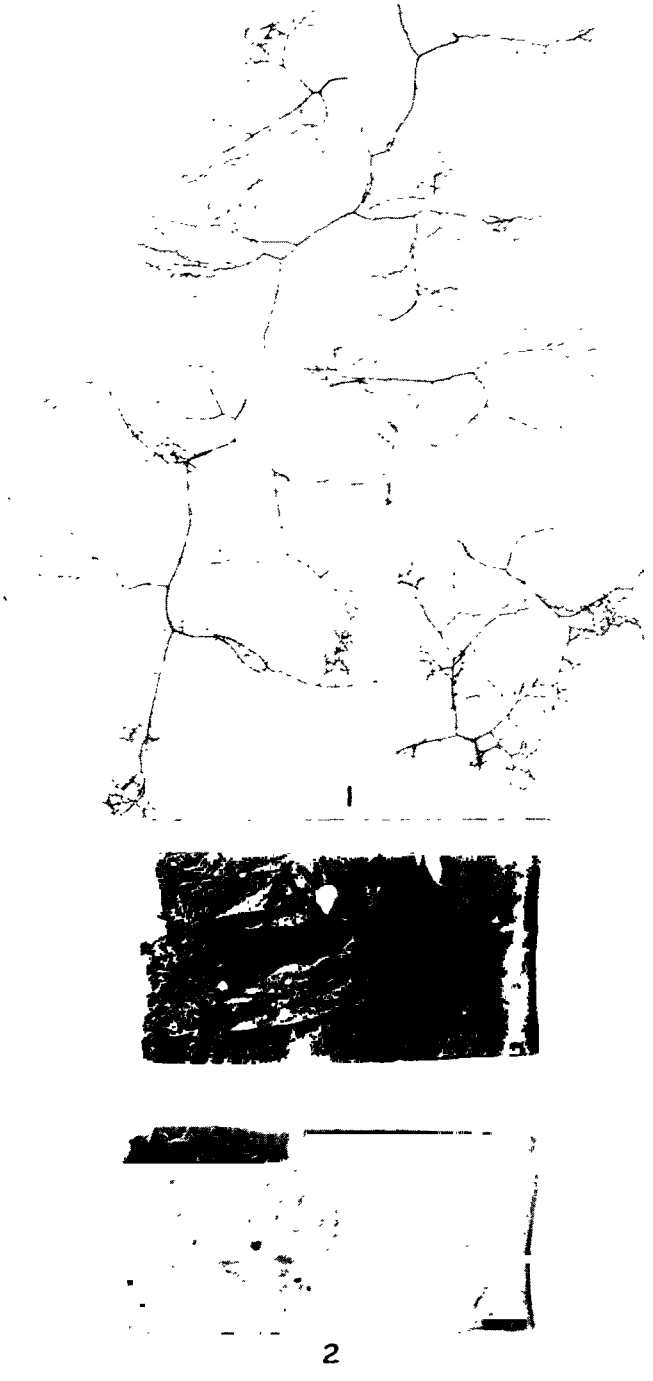
1, *Laminaria digitata* (L.) Lamour from Heleoland; 2, *Fucus vesiculosus* L. from Norway; 3, *Alaria esculenta* Grev. from California







1. The giant kelp *Macrocystis pyrifera* in its natural habitat. 2 and 3, a power-driven barge harvesting kelp. Courtesy of the Kelco Company



1, *Hypnea nidifica* J. Ag. 2, *Laminaria clouston*



1, *Ecklonia cava* Kjellm. from Japan, 2, *Nereocystis luetkeana* Post. and Rupr. from San Juan Islands, 3, *Chondrus ocellatus* Holm. from Japan, 4, *Fucus serratus* L. from Iceland

THE EXCAVATIONS OF SOLOMON'S SEAPORT: EZION-GEBER

By Nelson Glueck

Professor of Bible and Biblical Archaeology, Hebrew Union College, Sometime Director, American School of Oriental Research, Jerusalem

[With 14 plates]

Three seasons of excavations were conducted during the spring months of 1938–40 at Tell el-Kheleifeh, under the auspices of the American School of Oriental Research, Jerusalem, the American Philosophical Society, and the Smithsonian Institution. They resulted in the almost complete uncovering of Ezion-geber, and of Elath, as it was known in the latter part of its history. Tell el-Kheleifeh (pl. 1, fig. 1) is situated in the center of the southern end of the Wâdī el-'Arabah, on the north shore of the Gulf of 'Aqabah, the eastern arm of the Red Sea. It is about halfway between the northeastern and northwestern ends of the gulf, marked respectively by the modern village of 'Aqabah (pl. 1, fig. 2, and pl. 2, fig. 1) in Transjordan, and the police post of Mrashrash in Palestine. On the east side of the gulf is Sa 'ûdī Arabia, and on the west side is Sinai.

The discovery of Tell el-Kheleifeh and its identification with Ezion-geber:Elath were the result of archeological explorations, aided by some scanty references in the Bible. As a result of the archeological exploration of the Wâdī el-'Arabah, the great rift extending between the southern end of the Dead Sea and the Gulf of 'Aqabah, and known in the Bible as the 'Arabah, extensive copper- and iron-mining and smelting sites were discovered, which could be dated by the pottery recovered particularly to the time of King Solomon. One of these mining and smelting sites, called Mrashrash, directly overlooks the present shore line of the northwest corner of the Gulf of 'Aqabah. Near the east end of the north shore are located the extensive ruins of the Nabataean-Roman-Byzantine-medieval Arabic site of Aila, whose history goes back to at least the third century B. C. These facts compelled the conclusion, severals years before it was actually located, that the site of Solomon's seaport of Ezion-geber had to be situated somewhere along the present

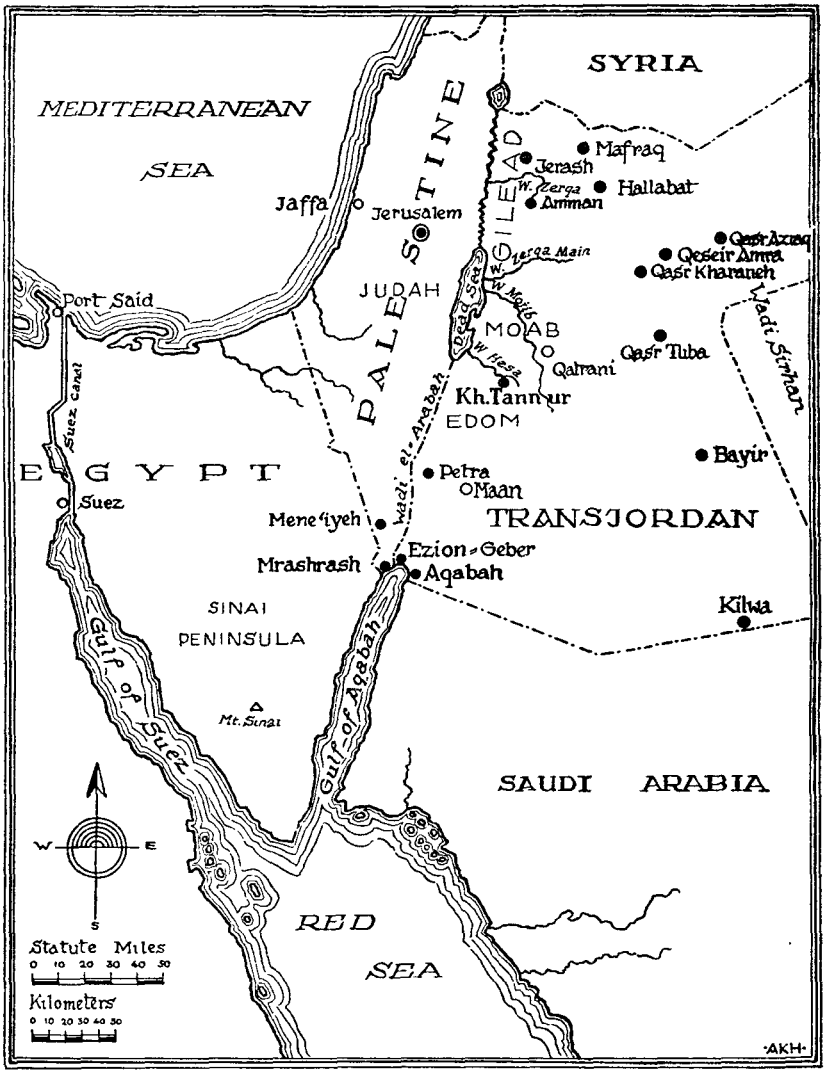


FIGURE 1.—Location of Ezion-Geber.

shore of the north end of the Gulf of 'Aqabah.[1] This was also in harmony with the statement in I Kings 9:26:

King Solomon made a fleet of ships in Ezion-geber, which is beside Eloth, on the shore of the Red Sea, in the Land of Edom.

Until the actual site of Solomon's seaport was discovered and excavated, the notion was current that it was to be located at a place

[1] Glueck, Nelson, Explorations in Eastern Palestine. Bull. Amer. Schools Oriental Res., No. 65, p. 12, February 1937; The first campaign at Tell El-Kheleifeh (Ezion-Geber). Ibid., No. 71, pp. 4–5, October 1938; Explorations in Eastern Palestine. Ann. Amer. Schools Oriental Res., vol. 15, pp. 26–27, 42–45, 47–48, 138–139, 1934–1935.

called Mene 'îyeh in the Wâdī el-'Arabah, some 30 kilometers north of the present shore line of the Gulf of 'Aqabah. This was believed in at a time also when it was not known that Mene 'îyeh was actually the site of one of the largest mining and smelting sites in the Wâdī el-'Arabah, worked intensively particularly during the time of King Solomon.[2] Other identifications have been with Ghadyân [3] and with a place near 'Ain Defîyeh,[4] which latter site is some 16 kilometers from the present shore of the sea. For various reasons, it had been thought that the waters of the gulf had retreated in the course of some three millennia from approximately 30 to 16 kilometers to the position of its present north shore. The waters of the Gulf of 'Aqabah, have, as a matter of fact, retreated during the course of the last 3,000 years, but the retreat measures about 550 meters, and not as many as 25,000 meters more or less. It remained for a German explorer, Fritz Frank, to discover the small mound of Tell el-Kheleifeh, which is situated about 550 meters from the shore and is about halfway between the eastern and western ends of the gulf.[5] He found large quantities of pottery fragments on the surface of the mound (pl. 2, fig. 2), which he judged to be old, earlier than Roman. When the expedition of the American School of Oriental Research, Jerusalem, subsequently examined the site, it was seen that the pottery there was the same as that at the mining sites in the Wâdī el-'Arabah, and that the main period of occupation of Tell el-Kheleifeh must be assigned to and after the time of King Solomon.[6] The excavations (pl. 3, fig. 1) have shown that in all likelihood Tell el-Kheleifeh is to be identified with Ezion-geber: Elath, although it cannot be archeologically demonstrated beyond all question of doubt. It is, however, now clear that the shore line of the north end of the Gulf of 'Aqabah has not changed appreciably in the last 3,000 years.

It would facilitate the identification of Ezion-geber greatly if we knew exactly where Elath was situated. Both sites, if indeed there ever were two separate sites, which we doubt, are at least to be sought in close proximity to each other, according to the Biblical passages referring to them. We have attempted to identify Eloth, or Elath, as it is variously called in the Bible, with the large ruined site of

[2] Glueck, Nelson, Explorations in Eastern Palestine. Ann. Amer. Schools Oriental Res., vol. 15, pp. 42–45, 1934–1935; Musil, Alois, Arabia Petraea. Vol. 2, pt. 2, pp. 186–190, Wien, 1908; Phythian-Adams, W. J., The call of Israel. Pp. 187–188. London, 1934.

[3] Cf. Glueck, Nelson, Explorations in Eastern Palestine. Ann. Amer. Schools Oriental Res., vol. 15, p. 45, 1934–1935.

[4] Cf. Glueck, Nelson, Explorations in Eastern Palestine. Ann. Amer. Schools Oriental Res., vols. 18–19, pp. 5–6, 1937–1939.

[5] Frank, Fritz, Aus der 'Araba, I. Zeitschr. Deutsch. Palästinavereins, vol. 57, pp. 243–244, 1934.

[6] Glueck, Nelson, Explorations in Eastern Palestine. Bull. Amer. Schools Oriental Res., No. 65, p. 12, February 1937; The first campaign at Tell El-Kheleifeh (Ezion-Geber). Ibid., No. 71, p. 4, October 1938; Explorations in Eastern Palestine. Ann. Amer. Schools Oriental Res., vol. 15, p. 48, 1934–1935; vols. 18–19, p. 3, 1937–1939.

Aila, several kilometers to the east of Tell el-Kheleifeh, and almost directly on the shore of the gulf. To judge from careful and repeated examinations of the surface pottery finds there, however, Aila was occupied from the Nabataean to the medieval Arabic period, but not before then.[7] The possibility remains, nevertheless, that if excavations were to be undertaken at Aila, sherds might be found indicating occupation of the site during and preceding the times of the Biblical Ezion-geber and Elath. I consider that possibility, however, to be a remote one, because the depth of ancient debris on the site of Aila is not considerable, and could not go below the Nabataean ruins without striking the water level. If there ever were any ancient sites at Aila, which could be related to the Biblical Ezion-geber or Elath, then in all probability their ruins were completely cleared away by the heavy and deep and extensive building operations which took place there particularly in the Nabataean, Roman, and Byzantine periods.[8]

The Biblical evidence, which we have gone into in detail elsewhere,[9] seems to indicate that Ezion-geber did not become a really important site until the time of Solomon, and figured as such in the biblical annals from the tenth to the middle of the ninth century B. C., after which time its name is no longer mentioned. It was replaced by Elath in the biblical accounts, becoming important in the eighth century B. C., near the end of which it passed from Judaean into Edomite control, and out of the Biblical record. There is reason to believe from the evidence in the Bible, that the Elath which succeeded Ezion-geber as an important site on the north shore of the Gulf of 'Aqabah, was built on the ruins of Ezion-geber, after that site had been abandoned for some time. It is not an uncommon happening for different names to be applied to the same ancient Biblical site during various stages of its history. Thus Qiryath-sēfer and Debîr are one and the same place, as are Hebron and Kiryath-'arbā.[10] In view of the fact, therefore, that Tell el-Kheleifeh is on the shore of the eastern arm of the Yam Sûf, the Red Sea, and that there is no other site on that shore which shows the proper early occupational history necessary for either Ezion-geber or Elath or both, and that the excavations of Tell el-Kheleifeh revealed that it was occupied from the tenth to the late fifth centuries B. C., including thus the main periods

[7] Glueck, Nelson, Explorations in Eastern Palestine. Bull. Amer. Schools Oriental Res., No. 65, p. 12, February 1937; The first campaign at Tell El-Kheleifeh (Ezion-Geber). Ibid., No. 71, p. 4, October 1938; Explorations in Eastern Palestine. Ann. Amer. Schools Oriental Res., vol. 15, p. 47, 1934–1935; vols. 18–19, pp. 6–7, 1937–1939.

[8] Glueck, Nelson, Explorations in Eastern Palestine. Ann. Amer. Schools Oriental Res., vols. 18–19, p. 3, 1937–1939.

[9] Glueck, Nelson, The topography and history of Ezion-Geber and Elath. Bull. Amer. Schools Oriental Res., No. 72, pp. 9–10, December 1938.

[10] Idem.

of both Ezion-geber and Elath as reflected in the Bible, we are compelled to conclude that Tell el-Kheleifeh is to be identified with Ezion-geber and Elath.

One of the chief difficulties at first of identifying Ezion-geber: Elath with Tell el-Kheleifeh, is the location of the tell in the center of the south end of the Wâdī el-'Arabah on the shore of the gulf, and not farther to the east nearer to 'Aqabah, at a place such as Aila, for instance. Assuming, as we do, that Ezion-geber is to be identified with the lower levels of Tell el-Kheleifeh, it is possible to say that the builders of the site could not possibly have chosen a more inclement site along the entire shore line. Situated in the bottom of a curve banked on the east side by the hills of Edom, which continue into Arabia, and on the west side by the hills of Palestine, which continue into Sinai, it is open to the full fury of the winds and sandstorms from the north that blow along the center of the Wâdī el-'Arabah as if forced through a wind tunnel. During the 1940 season of excavations, for instance, there was a blinding sandstorm which lasted almost continuously for 10 days, and made work on the tell practically impossible. By walking about a kilometer to the east or to the west of the tell, it was always possible to escape the winds and the accompanying sandstorms. Inasmuch as it is demonstrable that the physical conditions have not changed appreciably there during the last 3,000 years, the question which disturbed us before the commencement of the actual excavations was how the ancient architects and city planners had hit upon this particular place for the building of an important town. It is not difficult to understand why Solomon's port city could not have been built farther to the west. The shore is rocky there, and dangerous for ships. Furthermore, from Mrashrash, at the northwestern end of the gulf, to Tell el-Kheleifeh, there is no drinking water in a distance of about 3½ kilometers. The police stationed at Mrashrash send all the way to 'Aqabah, at the northeastern end of the gulf, about 7 kilometers' distance one way, for their drinking water. The point where the sweet-water wells begin is marked almost exactly by the location of the ruins of Ezion-geber. From there eastward toward 'Aqabah there is a continuous line of such wells, increasing in number the closer one gets to 'Aqabah, and becoming constantly less brackish, and marked by a correspondingly increasing number of date palms between the two points. Why, then, did the builders of Ezion-geber not locate their site nearer 'Aqabah, where the water is comparatively sweet, and where protection may be found under the lee of the hills from the strong winds and biting sandstorms that plague it in its present position? The strong winds that blow steadily from the north were evidently a feature so desirable to the architects of Ezion-geber that they built

it directly in the path of these winds, at the sacrifice of much convenience and comfort for its inhabitants.

The very first building uncovered gave the answer to this particular problem. The excavations were begun at the northwest end of the mound for various reasons, not the least of them being consideration for the direction of the winds, which would at least blow the debris being dug up away from, and not directly into, the eyes of the workmen. A large building containing originally three large rectangular rooms and three small ones was dug out, its walls more or less intact to about a third of their original height. It soon became evident that this was not an ordinary large building or palace, but a completely novel type of structure, the like of which had not previously been discovered in the entire ancient Near East. The walls of the rooms were pierced with two rows of flues, and the main walls were interconnected by a system of air channels inside the walls, into which the upper rows of flues opened (pl. 3, fig. 2). The lower rows of flues pierced the walls between the rooms. It is our present idea that the lower rows of flues were intended to permit gases forming in one chamber to penetrate into a second one and preheat its contents. In other words, not all of the rooms were fired at the same time, but were fired progressively. The upper rows of flues were used then to create a draft, the air being sucked throughout the entire length of the building toward the draft chimney, which we have reason to believe once rose over the southeast corner of the structure. The originally unfired yellowish mud bricks had been baked by the heat of the fires in the rooms to the consistency of kiln-fired bricks. It became evident that the building was an elaborate smelter or refinery, where previously "roasted" ores were worked into ingots of purer metal. It was obvious both from the sulfuric discoloration of parts of the walls, and from finished metal articles fashioned from the ingots produced, that the refinery at Ezion-geber was devoted mainly to copper, and in a lesser degree to iron. Great quantities of both copper and iron, especially copper, abound in the Wâdī el-'Arabah, in Sinai, and in northwestern Arabia.[11] In the complex of buildings surrounding the smelter were foundry and factory rooms, in which finished or semifinished articles were turned out for home consumption and for export. Ezion-geber was the Pittsburgh of Palestine. The rooms in its refinery were, so to speak, air-conditioned for heat, utilizing a natural forced-draft system to fan the flames in the furnace rooms, which in principle was related to the Bessemer principle of forced draft discovered less than a century ago.

[11] Glueck, Nelson, The first campaign at Tell El-Kheleifeh (Ezion-Geber). Bull. Amer. Schools Oriental Res., No. 71, p. 7, October 1938.

The fuel for firing the refinery was obtained in all probability in the form of charcoal from the wooded hills of Edom.[12] Layers of crushed ore were placed between layers of lime in thick pottery crucibles on top of a base of hard-baked, loosely packed clay debris. Piles of charcoal were then packed around and above the crucibles in the open furnace rooms of the refinery, and the rooms fired in successive order at proper intervals of time. In this wise do we reconstruct the method of refining the ores and firing the furnaces.

In view of the now-established character of the important smelter-refinery of Ezion-geber: Elath, which was used and reused in one form or another throughout practically the entire history of the site, it is possible to understand why the builders of ancient Ezion-geber chose the site they did for the founding of their fortified industrial establishment. They had in mind the needs of the large refinery they were planning to erect. After careful examination they chose the one site in the center of the south end of the Wâdī el-'Arabah, where the winds blew strong and constantly from an almost unvarying direction. They needed a constant draft from a known quarter to fan the flames in the furnaces of the refinery. Without these strong winds, for the sake of which they were willing to endure frequent sandstorms, they could not have erected such a large and elaborate refinery, and would have had to rely completely upon the hand-bellows system in vogue previously. The comfort of better water and a more protected location for the founding of their city was dispensed with by its builders in order to enable them to harness the elements for their industrial purposes.

Incidentally, the shore line in front of Tell el-Kheleifeh is free of the rocks which make the east and west ends of the north shore dangerous for boats. It was on such rocks, according to I Kings 22:49 that the fleet of Jehoshaphat, which he had had constructed in order to sail to Ophir in Arabia for gold, came to grief. Solomon's fleet, which made the trip to Ophir and back once every 3 years, according to I Kings 10:22 and II Chronicles 9:21, may have previously experienced a similar fate. The ships of both fleets were probably no larger than the small sailboats in which the fishermen put forth from 'Aqabah today. The requirement in Solomon's time was not a harbor with a deep draught for ships, but one which had a sandy bottom enabling ships to be dragged on shore. The main anchorage for Solomon's fleet may even have been farther to the east, approximately at the position on the shore line facing Aila, where, as we shall point out, some of the free residents of Ezion-geber: Elath may have tented. Solomon's ships brought back

[12] Idem, p. 10; Explorations in Eastern Palestine. Ann. Amer. Schools Oriental Res., vol. 15, pp. 26, 44, 1934–35.

various precious products from Arabia,[13] undoubtedly giving in exchange the copper and iron ingots and finished metal objects produced in Ezion-geber.

In addition to the fact that the entire first town of Ezion-geber, which for convenience we shall call Ezion-geber I, represented a carefully integrated industrial complex, the excavations have shown that it was built completely anew on virgin soil. It experienced no gradual growth and development but was built at one time, within the space of a year or two, from a preconceived and carefully worked-out plan. Surveyors, architects, and engineers had evidently looked over the north shore of the Gulf of 'Aqabah in advance with a view to the particular requirements they had in mind. They were industrial scouts, and chose a town site which no builders would have selected in the normal course of events for the founding of a settlement. They needed, as we have seen, strong and continuous winds, coming from a known direction to provide drafts for furnaces. They needed also sweet water to drink, a central point commanding strategic commercial and military cross roads, and access to the sea. Great quantities of copper and iron ore were present in the Wâdī el-'Arabah, and provided the most important impetus for the building of the first town on the site known today as Tell el-Kheleifeh.

The town site chosen, intricate plans for the establishing of a very complicated factory complex must have been drawn up. A great deal of specialized technical skill was necessary. Thick and high walls of sun-dried bricks had to be erected, with flues and air channels in them, and with allowances made for the weight of the wall above them. The angle of the buildings had to be chosen carefully to get the full benefit of the winds from the north. Bricks had to be made by the thousands, and laid by expert bricklayers. In no period in the history of the subsequent towns, each built on top of the ruins of the previous one, were bricks as excellently made and skillfully laid as during the first period. Certainly not in the poor little town of 'Aqabah several miles to the east, which in modern times has superseded Ezion-geber. All the bricks were laid in complicated systems of headers and stretchers, with the corners of the walls well bonded together. One reads today of new towns, planned in advance, and springing up as if by magic on previously bare soil with the aid of modern transportation facilities and mechanical equipment. Ezion-geber, however, still remote from civilized points today, was a long and difficult journey from them in ancient times. It took the writer 13 days on camelback, several years ago, to travel from the south end of the Dead Sea, which is already comparatively far from

[13] I Kings 10 : 2, 13, 15.

Jerusalem, to the north shore of the Gulf of 'Aqabah. It took a great deal of business ability, as well as architectural, engineering, and metallurgical skill, to construct the factory town and seaport of Ezion-geber, and to keep the production line going.

One can easily visualize the conditions existing about three millennia ago, when the idea of building this place was first conceived and then brilliantly translated into reality. Thousands of laborers had to be assembled, housed, fed, and protected at the chosen building site. As a matter of fact, most of them were probably slaves, who had to be guarded and goaded to work. Skilled technicians of all kinds had to be recruited. Great caravans had to be collected to transport materials and food. An effective business organization had to be called into existence to regulate the profitable flow of raw materials and finished or semifinished products. There was, so far as we know, only one man who possessed the strength, wealth, and wisdom capable of initiating and carrying out such a highly complex and specialized undertaking. He was King Solomon. He alone in his day had the ability, the vision, and the power to establish an important industrial center and seaport such a comparatively long distance from the capital city of Jerusalem.

The wise ruler of Israel was a copper king, a shipping magnate, a merchant prince, and a great builder. Through his manifold activities, he became at once the blessing and the curse of his country. With increased power and wealth came a centralization of authority and a ruthless dictatorship which ignored the democratic traditions of his own people. There resulted a counterdevelopment of forces of reaction and revolt, which were immediately after Solomon's death to rend his kingdom asunder. During his lifetime, however, Solomon reigned supreme. The evil he did lived after him. His far-flung net of activities extended from Egypt to Phoenicia, and from Arabia to Syria. Ezion-geber represents one of his greatest, if indeed up to the present time his least-known accomplishments. In the person of Solomon, more than anyone else before or after him, was fulfilled the promise to Israel, contained in Deuteronomy 8:9, according to which Israel was to inherit a land (the 'Arabah), "whose stones are iron, and out of whose hills you can dig copper."

A long period of mining, smelting, refining, and brickmaking must have preceded the construction of the elaborate refinery, unless one is to assume that experts were imported for the purpose, just as, for instance, Solomon imported Phoenicians to build and man his ships (I Kings 9:26-28; 10:11, 22). There is, however, no reason for that assumption. Mining and smelting and refining were known along the length of the 'Arabah at least from the beginning of the Early Iron Age, and quite probably already in the Early Bronze

Age. The Ḳenites, who were native to the country, and whose very name reveals that they were smiths, were the ones who probably introduced the Israelites, whose leader Moses had apparently taken a Ḳenite wife and who retained ever afterward the closest relationship with them, and the Edomites, to whom they were related through the Ḳenizzites, to the arts of mining and metallurgy. Was it from the Ḳenites that Moses learned how to make a copper serpent? (Genesis 21:9.) Saul was mindful of the close connection between the Israelites and the Ḳenites, and spared them in his battles with the Amalekites.

That the Ḳenites were at home in Edom and in the Wâdī 'Arabah is indicated by Balaam's punning proverb with regard to them in Numbers 24:21: "Everlasting is thy habitation, and set in the Rock (Sela) is thy Nest (Qēn)." The pun on Qēn and ʿenite (Qenite) is obvious, and Sela is to be identified with Umm el-Biyârah in Petra.[14] The Bible tells that Tubal-Cain (a Ḳenite) was the first forger of copper and iron instruments (Genesis 4:22). It is stated in I Chronicles 4:12–14 that the Ḳenizzites lived in the Valley of Smiths. We believe that this means the Wâdī 'Arabah, with its many copper and iron mining and smelting sites, and that the City of Copper mentioned in connection with the Valley of Smiths is to be identified with the large Iron Age mining and smelting site of Ḳhirbet Nahâs (the Copper Ruin), located near the north end of the Wâdī 'Arabah.[15] Confirmed wanderers, the Ḳenites seem to have retained throughout their history a Bedouin form of life, like the related Rechabites and Jerahmeelites. The presence of individual Ḳenites in Judah and Israel, pictured as wandering about from place to place, can be understood when it is realized that they were itinerant smiths.

The smelter-refinery was literally the center of the first Ezion-geber, or Ezion-geber I, as we shall call it. Some distance removed from it, and around it, was built a square of foundry and factory rooms. This industrial square was only one room thick. The rooms were formed by thin partition walls, between the spaced, parallel inner and outer walls. There seems to have been an entrance guarded by a strong square tower on the southwest side. The plan of the smelter, together with the industrial square, may be likened somewhat to that of a strong stockade wall, with a row of houses one room thick, built against the inside of the walls of the stockade square, and with an isolated, commanding building in the center of the square. There is, furthermore, some reason for believing that considerably beyond the industrial square, whose outer wall is strength-

[14] Glueck, Nelson, Explorations in Eastern Palestine. Ann. Amer. Schools Oriental Res., vols. 18–19. p. 26, 1937–1939.

[15] Glueck, Nelson, The other side of the Jordan. P. 83. Amer. Schools Oriental Res., New Haven, 1940.

ened like a fortress wall with regular offsets, there may have been in the very first period an outer, complex fortification system, consisting of two separate walls, with a glaçis built against each of them, and a dry moat between the two walls. All traces of it have disappeared because of a later fortification system much like it, which completely displaced it.

Both the smelter and parts of the industrial square were used and reused in later periods. Indeed, one of the main difficulties of the excavations consisted in just this fact: That wherever a later age found a good wall of a previous one, it frequently built other walls against it to form a new room. The employment of a straight stratigraphic method of excavation would have produced dire results. The problems of unraveling the puzzles of walls there, built against each other, yet frequently belonging to totally different periods, were baffling at first appearance, but usually could be solved. The frequent use of different types of bricks and different methods of bricklaying in different periods helped to distinguish one period from another. In certain parts of Tell el-Kheleifeh, walls of successive periods were built on respectively higher levels.

The intricate smelter-refinery of Ezion-geber: Elath was from the very beginning till near the end of the history of the place considered to be its most important structure. It underwent numerous changes in the course of time. The system of flues and air channels in the walls was abandoned after they had become filled with sand and soot. The flue holes were plastered over, and the smelting process reverted to the use of hand bellows. In this wise, the great industrial plant continued to function for a number of centuries longer. The tremendous heat in the furnace rooms of the smelter transformed the sun-dried bricks used in its construction into the equivalent of kiln-baked bricks. The copper sulfide fumes of the copper ores being reduced in the smelter turned its walls green; where the fumes did not come in direct contact with the walls, the heat turned them brown and red. Centuries of experience had produced a brick measuring 40 by 20 by 10 centimeters, with which an excellent wall two and a half bricks thick could be produced, of enduring strength. Some of the walls of the smelter have stood almost to their original height for nearly 30 centuries.

When finally heat cracked the walls of the smelter in places, and repairs and reinforcements were necessary, a means of strengthening them was employed, which had hitherto been applied only to fortresses. A sloping retaining wall in all respects similar to a fortification glaçis, was discovered during the third season of work, built against each side of the smelter. It was almost half again as wide at the bottom as the smelter walls themselves. Each row of

bricks in this supporting ramp was set about 2 centimeters back of the preceding row, so that by the time the top of the inward slope of the glaçis reached the top of the smelter wall, only the width of the smelter wall remained. The outer, very steep slope of this glaçis was then covered with a thick facing of strong mud mortar, which effectively hid all the irregularities of the tiny steps of its successively graduated rows of bricks, and presented a surface so smooth as not to afford a toehold to anyone desirous of ascending it. Although the glaçis around the smelter can in no wise be distinguished from a fortification glaçis, it was intended not so much to keep out an enemy as to bolster up the walls of the smelter.

The strength of this smelter glaçis was, furthermore, enhanced by the fact that while its outer face sloped inward as it went upward, the rows of bricks in it sloped downward somewhat toward the face of each of the walls against which the glaçis was built. In addition, the builders of this glaçis (and others like it in a later period at Tell el-Kheleifeh), employed a principle of tying the bricks to each other that was commonly used, for instance, in the Renaissance Period in Europe, particularly for fortress construction. The bricks were laid in complex, crisscross patterns. It is the strongest form of brick bonding known to man, and must already have been old when used by the brickmasons of Ezion-geber. By ascertaining the degree of the angle of the slope of the glaçis around the smelter, both the height of the glaçis and the original height of the walls against which it was built could be obtained. Allowing for the upward extension of the walls of the smelter above the top of the glaçis, it is possible to say that the smelter walls were about 4 meters high. There was no roof over the smelter. Naturally, when the strengthening glaçis was built against the smelter walls, the flue system could no longer function in the same manner as previously. The inside walls were completely plastered over, closing the flue holes from this side also. Just how the necessary draft was furnished for the furnaces is not clear to us. One thing is certain, namely, refining and, to a degree, smelting operations were continued in the smelter-refinery. The heat was so intense that the plaster covering the walls and the previous flue holes was literally fused against the walls. Perhaps flue holes were built in the walls above the level of the top of the glaçis; or perhaps the crude bellows system worked by hand was reverted to. Apparently the smelter-refinery was used in one form or another till the end of the occupation of Ezion-geber: Elath.

In all probability, the refinery and foundries and factories at Ezion-geber were manned for the most part with slave labor, even

as the mines in the Wâdī el-'Arabah were worked by slaves.[16] The fumes and smoke from the smelter-refinery alone, coupled with the severity of the natural conditions, would have made life there intolerable to the free-born, and impossible for slaves. The welfare of the latter, however, would hardly have been taken into consideration. The permanent population of Ezion-geber: Elath was never large, numbering probably not more than two or three hundred. During the essentially seasonal industrial activity there, the population figures must have increased considerably with the importation of slave labor. While the officers and merchants may have tented some distance away from the furnaces and foundries, the slaves, however, upon whom the main burden of the work fell, were probably confined inside the walled area. With them must have been a changing guard of a certain number of soldiers to control them and guard the site.

Not only did the smelter-refinery continue in use throughout the entire history of Ezion-geber: Elath, but the south and east sides of the industrial square were likewise employed throughout the entire history of the site. The north and west sides of the industrial square were destroyed, when, at the beginning of Period II, a new series of fortification walls was put up around Ezion-geber, in part perhaps on the line of former, outermost fortification walls which may have encircled the industrial square, and in part on entirely different lines. As a result of the new alinement of the fortification walls of Period II, the smelter-refinery which still remained the most important building, was no longer in the center of the site, but at its northwest corner. It consisted of two lines of defenses. There was a very strong inner wall, strengthened by regular offsets along its outer side. It was further strengthened by a strong glaçis built against it, with corresponding offsets (pl. 4, fig. 1). About 3 meters beyond the base of the glaçis was another fortification wall, about 1 meter thick and 3 meters high. It, too, seems to have been further strengthened by a glaçis built against it. It is probable that both this wall and the glaçis against it had offsets corresponding to those of the parallel inner wall and glaçis. Between the two walls ran a dry moat, the bottom of which was marked by a stamped-clay and mud-brick floor. At the corners of the major wall were towers, which in each instance overlooked the slopes of its glaçis. The smaller outer wall is much less well preserved than the larger wall, but it seems probable that it too had similar towers, one at each corner.

[16] Glueck, Nelson, Explorations in Eastern Palestine. Ann. Amer. Schools Oriental Res., vol. 15, pp. 28–44, 1934–35.

On the south side near the southwest corner was found a monumental gateway, with three pairs of doors and two opposite sets of guardrooms between them, which will be described in more detail later (pl. 5, fig. 1). The glaçis of each of the outer fortification walls is broken off before arriving at the gate, so it is impossible to say exactly what the connection between them and the gate was. This double-walled fortification extended a considerable distance south and east, respectively, of the industrial square, built in the preceding period of Ezion-geber I. On the north side, and part of the west side, however, it cut through and in part was built over the line of rooms of this industrial square, with no attempt to make use of its rooms on these sides. The rooms of the industrial square on the other two sides were reused. The north half of the outermost glaçis on the west side was built against the outermost west wall of the industrial square. It is interesting to note that the scheme of double-walled outer defenses with a dry moat between the walls, is known elsewhere in Transjordan. It is particularly clear at the Early Iron Age site of Khirbet el-Medeiyineh overlooking the Wâdi Themed.[17] It is difficult to understand why the builders of this complex fortification scheme in Ezion-geber II did not extend the outer walls beyond the north and west sides of the industrial square as they had on the south and east sides. Indeed, on the north side, the larger of the two fortification walls was built partly over the north side of the smelter, and over the glaçis built against the smelter on that side in the preceding period of Ezion-geber I.

The main wall had been built so well and so regularly that it was possible, after parts of it had been exposed, to plot out its course and determine its exact line, where it had not been completely weathered away or destroyed, by merely trenching at intervals along its length. At the now preserved top of the wall, which is almost flush with the level of the desert, being covered with a layer of debris, the wall is from 2.5 to 3 meters thick. Its foundation courses go down below the soil from 75 centimeters to a meter, and in many places the lowest foundation course rests on a natural, hard-clay stratum. As the wall goes downward, it widens out, sometimes in three successive steps of two rows of bricks each, with the result that in some places the wall is almost 4 meters thick at its base. It is built of sun-dried brick, like the rest of the site, laid carefully in alternate rows of headers and stretchers, and must easily have been 8 meters high. There are strongly marked offsets along the sides of the walls, and particularly at the corners.

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[17] Galling, Kurt, Biblisches Reallexikon. P. 372. Tübingen, 1937; Glueck, Nelson, Explorations in Eastern Palestine. Ann. Amer. Schools Oriental Res., vol. 14, p. 13, 1934; The other side of the Jordan. P. 143. Amer. Schools Oriental Res., New Haven, 1940.

After the outer fortification wall had been discovered, the search began for the main gateway leading into the town. It was found near the southwest corner of the wall, on the south side, facing the sea. There were three gates in this entrance way, built at intervals one behind the other, the first two of which opened respectively into separate sets of guardrooms behind each gate, with one room on each side of the entrance passage (pl. 5, fig. 2). Thus if the first gate were broken down, the enemy would enter a rectangular area formed by the two rectangular guardrooms facing each other on opposite sides of the entrance passage; and the same if the second gate were broken down. The third gate opened into the main street of the town, which made a sharp right-angle turn to the east. The third gate seems also to have led into a large open square, where the market place was undoubtedly located, and in a section of which the camels of visiting caravans may have been kept during the night time. The amazing thing about Ezion-geber II is that a place of such comparatively small size should be surrounded by such a strong outer double fortification wall, with its three-doored gateway. The entire site, walls and all, covers an area no larger than approximately an acre and a half—about large enough for a villa with a good-sized garden in a modern suburb.

The three-doored gateway of Ezion-geber II is to be directly related to the south gate of the inner town of Carcemish, as well as to the west gate of the outer town of Carcemish.[18] Evidence from Megiddo has shown that the gateway regarded by Guy as belonging to stratum IV at Megiddo, and which he compared with the south gate at Carcemish [19] may actually belong to stratum III, dated 780–650 B. C.[20] The plan of this gateway is closely related to that of Ezion-geber II, and it is probably based on an earlier plan contemporary with that of Ezion-geber II.

We consider it likely that when the nature of the Solomonic gateway at Megiddo has been definitely established, it will be shown to be almost, if not completely identical with the gateway of Ezion-geber II. Lankester Harding has called my attention to the fact that there is a gateway at Lachish, which the excavators have assigned to the tenth century B. C. and attributed to Solomon, which is almost a duplicate of the gateway at Ezion-geber II, and the comparable ones at Carcemish. We think it likely that Solomon's

[18] Wooley, C. Leonard, and Lawrence, T. E., Carcemish II. Pp. 82–85, pl. 12, 1921. Watzinger, Carl, Denkmäler Palästinas, I. P. 55, 1933.

[19] Guy, P. L. O., New light from Armageddon. Oriental Inst. Comm., No. 9, pp. 25–27, 44–48, 1931.

[20] Lamon, Robert S., and Shipton, Geoffrey M., Megiddo I. Univ. Chicago Oriental Inst. Publ., vol. 42, pp. 74–75, 1939; Amer. Journ. Archaeol., vol. 45, No. 2, pp. 289–290, 1941; Albright, W. F., Further light on the history of Israel from Lachish and Megiddo. Bull. Amer. Schools Oriental Res., No. 68, p. 25, December 1937.

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Ezion-geber was captured by Shishak's forces during the same campaign which resulted in the destruction of many towns in Palestine, including Megiddo, shortly after Solomon's death.[21]

It is significant that the offsets of the new fortification walls and of each glaçis of Period II are parallel to the offsets of the outer wall of the industrial square of Period I. Furthermore, the bricks of the glaçis built against each of the fortification walls of Period II, were laid in the same diagonal, crisscross fashion as the bricks in the glaçis built in Period I against the smelter-refinery. Were it not for the indubitable fact that part of this great fortification scheme of Period II in places cuts through and in other places is built over part of the rooms of the industrial square and the north side of the smelter-refinery with its glaçis of Period I, it would be possible to say that they are all to be assigned to the same period, and to overlook the differences in types of bricks used in the various constructions. The close relationship in manner of construction between the later fortification walls and glaçis and the earlier ones, makes it seem possible that the Period II fortification scheme replaced a similar earlier one. If this is so, then we may date all of Ezion-geber I to the tenth century B. C., to the time of Solomon, and then perhaps Ezion-geber II may be assigned to the ninth century B. C. More particularly, Period II may represent a reconstruction by Jehoshaphat of Judah, who reigned about 873–849 B. C. He was the one, it will be recalled, who made the abortive attempt to revive the sea trade between Ezion-geber and Arabia, which had flourished during the reign of Solomon. We are told that Jehoshaphat had a new fleet of Tarshish ships built to sail to Ophir for gold. No sooner were they completed, however, than a gale blew them on the rocks several kilometers from Ezion-geber, where they foundered. The venture was thereupon abandoned. The very attempt, however, must have meant that Ezion-geber received a new lease on life. Its defenses would have been restored, and its industrial activities renewed with full intensity. Exports, such as ingots and objects of copper and iron, would have been made ready for the ships to carry to Arabia in return for the products obtainable there. After the destruction of his fleet, Jehoshaphat may have relied upon camel caravans for transport.

The possibility exists also that Periods I and II represent early and late phases of building coinciding with the earlier and later parts of the reign of Solomon. Both would be the direct result of his great program of public works, which dotted Palestine with buildings of all kinds and Ezion-geber II would have continued in use during the reign of Jehoshaphat. We find it significant that at the

[21] Glueck, Nelson, The second campaign at Tell El-Kheleifeh (Ezion-Geber: Elath). Bull. Amer. Schools Oriental Res., No. 75, p. 18, October 1939.

very end of the account in I Kings 9 of Solomon's manifold building activities throughout Palestine, there is narrated in some detail the story of the construction of a fleet of ships for him at Ezion-geber, which, manned by Phoenician sailors, sailed to Ophir for gold. For some reason or other, the author of this account failed to mention that Solomon exported copper and iron ingots and finished products on these ships in exchange for the gold and other products obtainable in Ophir. He also failed to mention that shortly before, or shortly after, or at the same time as the ships were being constructed, the port city and industrial town of Ezion-geber was being built. After the time of Jehoshaphat, the name of Ezion-geber disappears from the Bible. It fell into the hands of the Edomites.[22]

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[22] During the reign of Joram, the son of Jehoshaphat, Edom revolted against Judah and regained her complete independence (II Kings 8:20–22; II Chron. 21:8–10). In all probability the 'Arabah and Ezion-geber reverted to Edomite control. In fact, if there was a Judaean garrison at Ezion-geber, as seems likely, then in all probability the town was beseiged and sacked and the garrison put to the sword. In a word, the successful rebellion may well have resulted in a destruction of Ezion-geber shortly after the middle of the ninth century B. C. Once communications between Judah and Ezion-geber were cut, as they must have been when Edom successfully shook off the Judaean control which had been imposed upon her by David, it would have been impossible for the Judaean garrison to have resisted for long. For about half a century Edom retained her independence, and then lost it again to Judah. Amaziah of Judah (c. 797–779 B. C.) waged successful war against Edom and captured Sela', which he renamed Joktheel (II Kings 14:7; II Chron. 25:11–12). His capable son, Uzziah, rebuilt Elath and restored it to Judah (II Kings 14:22; II Chron. 26:1–2). Ezion-geber is no longer mentioned, and, so far as the Biblical accounts are concerned, it had, from the time of Joram of Judah (c. 849–842) on, ceased to exist. It plays no further role in the historical accounts, being passed over as completely henceforth as Elath had been previously.

A lot must be read between the lines of the statements in II Kings 14:22 (II Chron. 26:1–2) that Azariah (Uzziah) "rebuilt Elath and restored it to Judah." It is clear that the city that was lost when Edom first regained her independence from Joram of Judah was Ezion-geber. We are told, however, that it was not Ezion-geber but Elath which Uzziah restored to Judah. What then had happened to Ezion-geber during the seventy-odd years that intervened between the time when Edom regained her independence from Joram of Judah and lost it again to Uzziah of Judah—figuring from the beginning of the reign of Joram to the beginning of the reign of Uzziah?

There are two possible explanations that suggest themselves. The first is that Ezion-geber was utterly destroyed and left abandoned by the Edomites when they captured it from Joram's troops, while they occupied the insignificant neighboring site to the east of it, called Elath, which had fallen to them at the same time as Ezion-geber. It was then this Elath which Uzziah built or rebuilt (perhaps it, too, had been partly destroyed) and restored to Judah. The question rises immediately, how could he *restore* Elath to Judah, when, at least so far as we know, Elath had never been lost, it being Ezion-geber that had passed out of Judaean control? The alternative explanation is that when Ezion-geber was captured and destroyed by the Edomites in the time of Joram, it was abandoned for many years and there was no settlement of any moment at the head of the Gulf of 'Aqabah, with the exception of the small, straggling site of Elath. This may have been nothing more than a tiny collection of mud-brick houses somewhat to the east of it. Not being strong enough to develop into a sea power, Edom was not able to make out of Elath what Judah had created out of Ezion-geber. Actually Edom probably no longer controlled the head of the Gulf of 'Aqabah from the time of Amaziah on, having held it in what seems to have been little more than nominal control for about 50 years. Meanwhile Ezion-geber lay a sand-covered ruin, which differed little in appearance from the sand hillocks in the vicinity. Even the name of Ezion-geber may no longer have been heard, because two full generations had passed by since it was destroyed. In the course of time it may gradually have become identified with Elath—as belonging to Elath. When Uzziah came to the south end of the 'Arabah, he actually built on top of the former site of Ezion-geber, which had become identified with Elath. The reasons that had impelled Solomon and Jehosha-

Inasmuch as Ezion-geber I is the very first settlement built upon the present site of Tell el-Kheleifeh, with all its walls resting on virgin soil and no traces whatsoever of earlier buildings, it becomes necessary to conclude that this Ezion-geber I is not the Ezion-geber which the Israelites saw when they emerged from the Wilderness of Sinai after the sojourn there lasting 40 years. The Ezion-geber they saw was probably a tiny, straggling site, with a few mud-brick huts, and a few scraggly palms, and must have been situated farther to the east, where the drinking water is less saline, and the sandstorms blown by the strong winds down the center of the 'Arabah do not occur. All traces of this earlier site of Ezion-geber have disappeared, only its name surviving in the bustling town of Ezion-geber, first built probably by Solomon in the very path of the winds blowing down the center of the 'Arabah.

A most interesting grave was found, sunk partly into the floor level of the dry moat between the two outer fortification walls of Period II on the north side, a short distance removed from the smelter-refinery (pl. 4, fig. 2). It may possibly be the grave of the man who directed the construction of this elaborate system of fortifications, and who died perhaps shortly after the walls were completed. The top of the large mud-brick, mastabahlike grave was covered with a layer of granite boulders, resting over a mud-brick roof. The grave had already been anciently disturbed, and whatever of intrinsic value it contained stolen, probably by some one familiar with its contents. An interesting amount of material still remained in the grave, however, when we opened it. It was found to contain a large

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phat, for instance, to occupy and extend Ezion-geber and to develop it into an industrial center and a seaport must have been as valid in Uzziah's day as in theirs. It was Ezion-geber, now known as Elath, which Uzziah *restored* to Judah. It is this alternative possibility which we believe to be the more likely one. It is possible to *restore* to someone only something which was previously owned. Thus in II Kings 16:6 we read that the Edomite king drove out the Judaeans from Elath and *restored* it to Edom. If the Ezion-geber of Solomon and Jehoshaphat and the Elath of Uzziah can be identified with each other, then the Biblical difficulties with regard to them disappear, and the archeological ones resolve themselves into understandable relationships.

After the time of Uzziah, Elath was to change hands once more, being lost by Judah to Edom in the time of his grandson, Ahaz. Taking advantage of Ahaz' distress during the Syro-Ephraimitic war in 735 B. C., the Edomites regained control of Elath. II Kings 16:6 should be amended to read: "At that time the king of Edom restored Elath to Edom, and drove out all Judaeans from Elath; whereupon the Edomites came to Elath, and dwelt there to this day."

After that time Judah was never again strong enough to dispute Edom's control over the 'Arabah and Elath. Edom thereafter became progressively less able to exploit the mineral wealth of the 'Arabah and to hold Elath. Adadnirari, and particularly Tiglath-pileser III, Sargon, Sennacherib, Ezarhaddon, and Assurbanapal, held Edom as a vassal state, and as the Assyrian records show, the Arabs harried the Edomites with increasing force. (See Glueck, Nelson, The topography and history of Ezion-Geber and Elath. Bull. Amer. Schools Oriental Res., No. 72, p. 9, December 1938.) The political power of Edom was really completely at an end when Nabonidus made Teima his main seat of residence. The rapidly rising Nabataeans took over the remains of the Edomite kingdom, infusing it in time with new life and power. From their time onward, a new site, Aila, was selected for settlement nearer the east end of the head of the Gulf of 'Aqabah.

number of human, animal, and fish bones, most of which, unfortunately, had almost completely disintegrated. It soon became obvious that only one person had been buried there. Several fragments of the skull were recovered, as well as part of a lower jawbone, with several teeth still embedded in it. Careful sifting of the debris in the grave yielded 24 human teeth. With the dead person, probably a man, were found the remains of a camel. It may well have been his favorite *dhalûl*, his racing camel. Next to the skull fragments were two three-handled jars, the only ones of the type recovered in the excavations. Inside one of them was a delicate little bowl, containing bones of a small bird, a small animal, and a fish. The joints of the spine of a large fish could be seen in position. The last meal provided for the final journey of the buried man was a sumptuous one. A millstone, a mortar, and a fragment of a cosmetic palette were also found in the grave. This burial is the earliest one belonging to an historic period ever discovered in a controlled excavation in Transjordan. Trenches were run in all directions from this one grave in an attempt to discover others, but in vain. It seems safe to assume, however, that there could not have been many burials as comparatively elaborate as the grave in the dry moat. The bricks in the rectangular grave were of the same size as those in the fortification walls of Period II. The walls of the grave were rather thin, having the thickness of only the width of a brick. The rectangular grave measured about 3 by 1.80 meters.

Not only was it possible to trace the complete line of the fortifications of this period, but part of the very brickyard was discovered, from which the bricks were taken for the building of the fortification walls. It is to be remembered that in Period II, the site was still more on the order of a large caravanserai than of a settlement proper. With the exception of the smelter-refinery, and the south and east sides of the industrial square which had escaped being destroyed or built over and were consequently reused in Period II, there was nothing else inside the enclosure formed by the fortification walls. There remained a great courtyard, in which the trading caravans may have rested at nighttime.

At the southeast corner of this great compound were left long rows of rectangular bricks, of exactly the same size as those used in the construction of the fortification walls of Period II. For the construction of these walls thousands upon thousands of sun-dried mud bricks were necessary. The areas inside and outside the proposed lines of the fortification walls were transformed into huge brickyards. Bricks were made and then laid out to dry in symmetrical rows, with spaces between each row and spaces between each brick to enable the rays of the sun to get at each brick from all directions. First the

bricks were laid flat and then placed on their sides. As soon as they had dried, they were brought to the bricklayers, who with great skill placed them in long and intricate rows of headers and stretchers till the walls of the desired thickness and height were obtained. When the new fortifications were finished, hundreds of bricks still remained in position in the southeast corner of the compound, where they had been placed to dry during the last stages of construction. In time, both before and after the settlement of Period II had been destroyed, they were covered with debris and sand, and were completely lost sight of and forgotten. In the following Period III, new houses were built over the buried rows of bricks, which could have been used in the construction of these houses had their builders but known of their existence.

The bricks of Tell el-Kheleifeh were, on the whole, exceedingly well made. Good clay, obtainable directly on the site, was used. It was mixed with straw of a kind, perhaps palm-tree fibers, which served as an excellent binding material. Usually, in addition, charcoal and fragments of shells and bones were mixed in with the clay. In ancient Egypt it was correctly thought to be the height of hardship to be compelled to make bricks without being supplied with the necessary complement of straw. We read in Exodus 5:10 ff.:

> And on that day Pharoah commanded the taskmasters of the people and their officers, saying, "Ye shall no more give the people straw for themselves; nevertheless, ye shall still exact from them the same number of bricks as they previously made, nor shall ye reduce the number."

An idea of the excellence of the ancient bricks found in Tell el-Kheleifeh can be obtained by comparing them with the modern, sun-dried bricks used in present-day 'Aqabah. In April 1940, a teriffic rain and hail storm literally washed half of the mud-brick village away. Many of the mud-brick walls simply dissolved. A few days later, the natives began to make new mud bricks and dried them in the sun, preparatory to repairing the damage. Their bricks were made without any binding materials whatsoever except lumps of dried mud from which the sand content had been more or less washed away by the rains. Small wonder that such bricks go to pieces during the first heavy rain! With some trepidation we returned to the excavations after the rains were over to see what damage had been done to the exposed ancient mud-brick walls of Tell el-Kheleifeh. We found upon our arrival that not only had they not suffered at all, but that even the unattached bricks of the ancient brickyard had not suffered the slightest harm. It is not surprising, therefore, that the mud-brick walls of Ezion-geber: Elath, built more than 2,500 years ago, have survived in some instances almost intact, while the mud-brick walls of modern 'Aqabah crumble and collapse not long after they are built.

The settlement of Period III was built partly over and partly against the walls of Period II, and utilized the old line of fortification walls. The easiest way of distinguishing the settlement of Period III from that of Period II, at least in the southeast corner, is that its walls rest on the debris and sand covering the remaining lines of bricks of the brickyard of Period II. In several instances the foundations of the walls of Period III encountered and cut through some of the bricks of Period II, which had been placed on their sides in the second stage of drying. The builders of Period III must have thought that these were isolated bricks. Had they dug down less than a foot they would have found all the old bricks, and would undoubtedly have utilized them in their new buildings. In addition to making use of the smelter-refinery and the still existing rooms of the industrial square, the entire area of the rest of the site was filled with houses in Period III. For the first time in its history the place assumed the semblance of a real village, and not merely a large, fortified, industrial plant. Essentially, however, it remained an industrial settlement with obviously a large amount of industrial work carried on also in private homes.

If the settlement of Period I is to be assigned to the tenth-ninth centuries B. C. and that of Period II to the same time or solely to the ninth century B. C., the settlement of Period III is to be assigned to the eighth century B. C. when it became known as Elath. It may have been constructed by Uzziah, who ruled from about 779 to 740 B. C.

The city of Period III, which is Elath I, functioned again as an industrial town of much the same nature as its predecessor. The gateway in the outer fortification system was altered, without any changes now apparent being made in the walls themselves, of which only the foundations remain. Some repairs or changes were probably effected in their superstructure.

The main changes in the gateway, in addition to the fact that the floor level was considerably raised, are that the entrances to the two pairs of guardrooms were blocked up, creating thus four small, squarish rooms behind the passageway, and an additional mud-brick pier was built on each side of the third gateway, narrowing the passageway considerably. In other words, the general scheme of the gateway of Period II with three doors was adhered to, but the guardrooms were transformed into casemates. A somewhat similar filling up of the guardrooms in the Megiddo gateway discussed above seems to have taken place.

In a room belonging to Period III was found a beautiful signet ring. The seal itself, enclosed in a copper casing, had incised on it in retrograde, in the clearest possible ancient Hebrew characters, the following inscription: *LYTM*, meaning, "belonging to Jotham" (pl.

6, fig. 1). Below the inscription is a beautifully carved horned ram, which seems to be Syrian in style. In front of the ram seems to be the figure of a man. It cannot definitely be proved that the *YTM* of the seal is the very king Jotham (c. 740–736 B. C.) of Judah, whose dominion included also Elath, but the likelihood is a strong one. In all events, it is quite appropriate that during the period of Judaean control over Elath extending throughout the reigns of Uzziah, Jotham, and the beginning of the reign of Ahaz, the Hebrew name of Jotham should be found, while during the Edomite rule of Period IV, the Edomite name of Qausanal should occur, as we shall see (pl. 6, fig. 2).

After the settlement of Period III had been destroyed by a terrific conflagration, a completely new industrial village was built over its ruins. This settlement of Period IV was Edomite. Its history can be divided into three clear subperiods. The history of Period IV, extended from about the end of the eighth century B. C. to about the end of the sixth century B. C. The new industrial village continued, like that of Period III, to use the system of fortifications that had been erected in Period II. Industrial operations continued on a fairly extensive scale. It is to the first phase of Period IV, which probably extended well down into the seventh century B. C. that we now assign the jars discovered in the previous season of excavations, stamped with a royal seal in ancient Hebrew-Edomite characters reading: "Belonging to Qausanal, the Servant of the King." It is thus now possible archeologically to fix a date for the Qausanal seal impressions which harmonizes with the one proposed for them by Albright on the basis of epigraphy alone. Qausanal is a typical Edomite name, the first part of which, Quas. is the name of a well-known Edomite and then Nabataean deity.[23] It seems likely that this Qausanal, who was probably an Edomite, was the officer commanding the district of Elath, and was the representative ("servant") of the Edomite king of the time.

Belonging to Period IV are the fragments of a large jar, on two pieces of which were incised the first ancient South Arabic letters ever discovered in a controlled excavation (pl. 7, fig. 1). Ryckmans considers these letters to belong to the Minaean script.[24] The Minaeans are reputed by Pliny to be the oldest known commercial people in South Arabia, controlling the Incense Route and monopolizing the trade in myrrh and frankincense. It has been possible since the discovery of those fragments to put them together, and

[23] Glueck, Nelson, The third season of excavation at Tell El-Kheleifeh. Bull. Amer. Schools Oriental Res., No. 79, p. 13, October 1940.

[24] Ryckmans, G., Un fragment de jarre avec caracteres minéens à Tell El-Kheleifeh. Rev. Bibl., vol. 48, pp. 247–249, 1939; Glueck, Nelson, The first campaign at Tell El-Kheleifeh (Ezion-Geber). Bull. Amer. Schools Oriental Res., No. 71, pp. 15–16, October 1938.

thus to restore most of the shape of the jar, which may well have been the container of precious products brought from as far as South Arabia. It may also possibly have belonged to a Minaean trade representative living in Elath. This discovery emphasizes the intimate commercial relationship between Ezion-geber: Elath and Arabia, and underlines anew the importance of Ezion-geber: Elath as a trade center and seaport, in addition to being an important industrial site. Miss Caton-Thompson and her colleagues have recently discovered some South Arabic inscriptions during the excavation of the temple at Hureidha, apparently first built in the fourth century B. C.[25] They are similar in type to the Minaean characters found incised on the jar at Tell el-Kheleifeh. The Hureidha inscriptions thus again furnish an approximate date—less definite, to be sure, than that obtained from the excavations at Tell el-Kheleifeh—upon which the history of the South Arabic type of ancient Arabic writing can be pegged. The distance between Ezion-geber and Hureidha is approximately 1,200 miles, and at least four centuries intervene between the South Arabic inscriptions found at the two sites. It begins to appear, however, that both places were set in one cultural pattern, and that Arabia continued into what is today called Transjordan, and thus in ancient times almost literally abutted the territory of Israel. To this day, for instance, the "skyscraper" houses of southern Arabia, described in recent books such as Freya Stark's "Southern Gates of Arabia," linger on in ruined form as far north as Ma'ân in southern Transjordan. Ezion-geber: Elath and Hureidha are at opposite ends of the great Spice Route. A site at the southern end of this great trade route, contemporary with Ezion-geber: Elath, is bound to be found.

In addition to the sea and land trade with Arabia, evidence was discovered of trade with Egypt and Sinai. There were found such varied objects coming from Sinai or Egypt as carnelian, agate, amethyst, and crystal beads, cartouche-like seal impressions, a tiny, faience amulet head of the god Bes, a Bubastite cat (pl. 7, fig. 2), fragments of alabaster cups and plates and buttons, and a part of a scaraboid bead.

To a later phase of the Edomite settlement of Period IV belongs a small storeroom near the southeast end of the mound. In it were four beautiful jars, three of them as intact, with the exception of a crack in one of them, as when they left the potter's wheel about 2,500 years ago. One of the jars was partly broken. The mouth of this jar had been closed with a heavy stone stopper, and further sealed

[25] Caton-Thompson, G., Geology and archaeology of the Hadhramaut, Southwest Arabia. Nature, vol. 142, No. 3586, pp. 139–142, July 23, 1938; A temple in the Hadhramaut. Asia, May 1939, p. 299.

with a clay covering, over which a large curved fragment of pottery had been placed. The heavy debris which had fallen on top of the jars, when Period IV was destroyed, had resulted in the cracking of the jar and the partial crushing of its top by the stone stopper. As a result, the obviously valuable contents of the jar had seeped out or evaporated. Another one of these storage jars was found to be full of resin, as sweet smelling today as it was two and half millennia ago. When this jar had been removed from the ground and left for a while at a tilted angle in the sun, the resin began to melt and flow over the mouth of the jar. It is a matter of speculation for what purpose this store of resin may have been intended in Elath. Some of the resin may have been used, for instance, in the ship-building industry which flourished at Ezion-geber and its successor Elath. More of it was used, in all probability, in connection with the smelting and refining and metal-manufacturing activities carried on so intensively there.

The settlements of Period IV were destroyed in turn, and a new industrial village was built, with its walls, for the most part, on lines entirely different from those of the previous ones. Not much of the settlement of Period V is left, but it had possibly two phases. Its history lasted from about the end of the sixth century or the first part of the fifth century B. C. down to the fourth century B. C. To this last settlement of Period V belong numerous sherds of Greek pottery transported from Athens to Gaza by ship and sent then by camel train to the north shore of the Red Sea, and reexported from there to Arabia.

In these Greek jars were contained wines and other products shipped to Elath, and thence to Arabia, in return for the incense and spices and other wares obtainable there. Aramaic ostraca were found in this level during the previous season, belonging to the fifth-fourth centuries B. C., and thus in part contemporary with the Attic wares found with them. One of the ostraca was a wine receipt (pl. 8, fig. 1). Another ostracon consisted of a fragment of an eighth-seventh century cooking pot, with profiled rim and loop handle. The ink inscription was on the inside surface of the sherd. It made a very convenient piece of writing material, because the scribe could grasp the handle of the fragment of pottery, while he dipped his brush into the vegetable ink and brushed on the letters, many of whose lines, unfortunately, are very faint. The inscription is Aramaic, and contemporary with the ostraca previously discovered, despite the fact that the sherd itself belongs to an earlier age.[26]

[26] Glueck, Nelson, Ostraca from Elath. Bull. Amer. Schools Oriental Res., No. 80, pp. 3–10, December 1940; No. 82, pp. 3–11, April 1941.

The settlement of Period V was the last one to be built on the site. The next one was moved to Aila, near 'Aqabah, and owes its origin to the Nabataeans and its present repute to the Romans, who made it the end of the famous highway of Trajan.

In one of the houses which may be assigned to Period IV was found a pottery plaque representing the pregnant Mother-Goddess, the goddess of fertility. It was made with conspicuous crudeness, and is startingly ugly. It must have been considered crude and ugly even when it was first fashioned. Why the potters of Ezion-geber: Elath chose to turn out figurines of deities in such ungracious forms, when at the same time some of the pottery they produced was of exquisite shape with beautiful decoration, is beyond comprehension. Was it the desire to reproduce something to which the crudity of the elemental was still attached? A figurine of equal ugliness, representing the same type of fertility goddess, was found in another room. With it was found a tiny cup, in which incense may have been burned. It is reasonable to believe that at Ezion-geber: Elath—a junction of the great incense routes between Arabia and Egypt and Palestine and Syria—this commodity must have been comparatively cheap (pl. 8, fig. 2). The favor of the gods must have been sought in clouds of sweet-smelling smoke. The piety of the people induced them also, when building a new house, to place some sort of a foundation offering under one of the walls. These offerings consisted at Elath of pots filled with fruits of the ground and fowl of the air and fish of the sea. In one instance a number of household utensils were carefully placed in a pot and the wall was then built over this foundation offering.

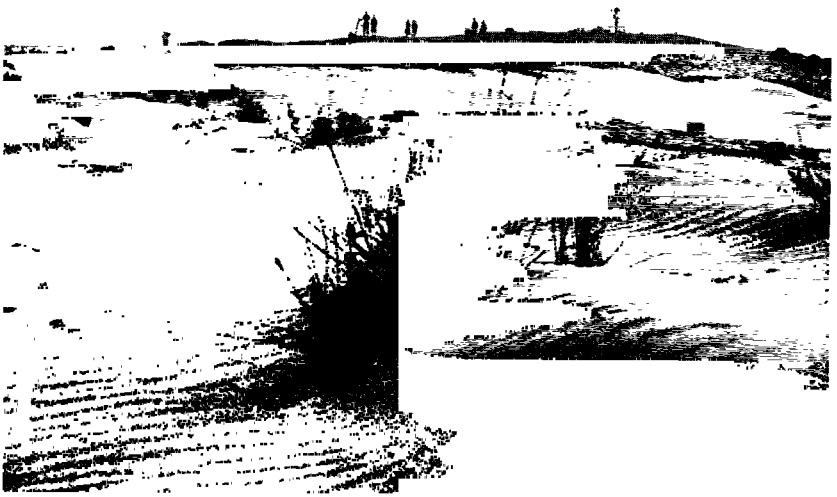
All manner of copper and iron objects were discovered in the excavations. They included copper fishhooks, iron gaffheads with barbed points, copper arrowheads and spear points, fibulae, fragments of fine copper dishes and tools, iron hoes and knives (pls. 9, 10, and 11, fig. 1). It seems likely that the coppersmiths of Ezion-geber: Elath, like their Egyptian contemporaries, possessed the secret of tempering copper to such a degree of hardness that it could be used for tools and drills. For both fine and coarse work, however, stone hammers and drills were also used, in addition to metal tools. Fine quartz pebbles were found, obviously brought in from elsewhere, which had evidently been used, to judge from their abraded ends, as hammers to shape fine metal jewelry. Other hard stones of varying sizes and coarseness were notched and grooved, so that a forked handle could be tied to them with thongs (pl. 11, fig. 2) Similar stone hammers were commonly used, for instance, by the American Indians. Stone drills were also found in the excavations, almost exactly like those found among the North American Indians. Egyp-

tian stone dishes and alabastra, fascinating pottery incense stands and censers, amethyst, agate, carnelian, quartz, and shell beads, and a fragment of a gold earring were among some of the other small finds.

Much of the material found at Ezion-geber: Elath has a flavor all its own, and some of it is distinctly unique. The horn- and ledge-handled, hand-made pots, many of them built up on straw mats, are without parallel elsewhere. Filled with ore, some of them were probably set inside furnaces or crucibles. They could then be drawn out by tongs fitted underneath their horn handles, turned upside down, and the molten metal in them poured out. A good quantity of the fine, painted and burnished ware which has come to be known as typical of the Early Iron Age pottery of Edom and Moab, was recovered. A peculiar kind of pottery of excellent make was discovered, with bands of protruding dentilated ornamentation. In general, the impression obtained from the three seasons of excavations is that despite the long control exercised over Ezion-geber: Elath by the Judaeans, its population, pottery, and general cultural patterns fit in more with the picture of Eastern Palestine, North Arabia and Sinai, than with Western Palestine. Edomites, Kenites, Kenizzites, and Arabs formed the bulk of the population, among which, however, were numbered Phoenicians, Egyptians, Judaeans, and in time, Babylonians, Persians, and Greeks.

The archeological exploration of northwestern Arabia will undoubtedly reveal sites closely related to Ezion-geber: Elath. A new archeological survey of Sinai is also necessary, in the light of the discoveries referred to in this article, showing again the intimate connections between Sinai and greater Palestine. The Wâdī el-'Arabah, the Gulf of 'Aqabah, and the peninsula of Arabia and Sinai are bound to become increasingly more important in the future. The copper, iron, gold, and spices of these lands, which were the sources of their wealth in ancient times, have been superseded in modern times in the same lands by oil. There is oil in the Wâdī el-'Arabah, and the sands of Arabia are merely a desert top over a very great oil reservoir. Manganese is probably present in the Wâdī el-'Arabah, in Sinai, and Midian. The day is not far off when great industrial plants, modern versions of that of Ezion-geber: Elath, will dot these lands, as in some places they already do, and tremendous caravans will again course through their wastes.

And the everlasting Bedouins, content in the enduring strength of their weakness, will pause and wonder at yet another transient phase of civilization, over whose ruins, if the experience of the past repeats itself, their descendants will some day pitch their rude tents.



1. VIEW OF TELL EL-KHELEIFEH, LOOKING NORTHEAST BEFORE BEGINNING OF EXCAVATIONS



2. LOOKING SOUTHWEST OVER MODERN VILLAGE OF 'AQABAH AND OVER NORTHWEST END OF GULF OF 'AQABAH.



1. EXPEDITION HOUSE IN 'AQABAH.



2 SORTING POTTERY AT EZION-GEBER

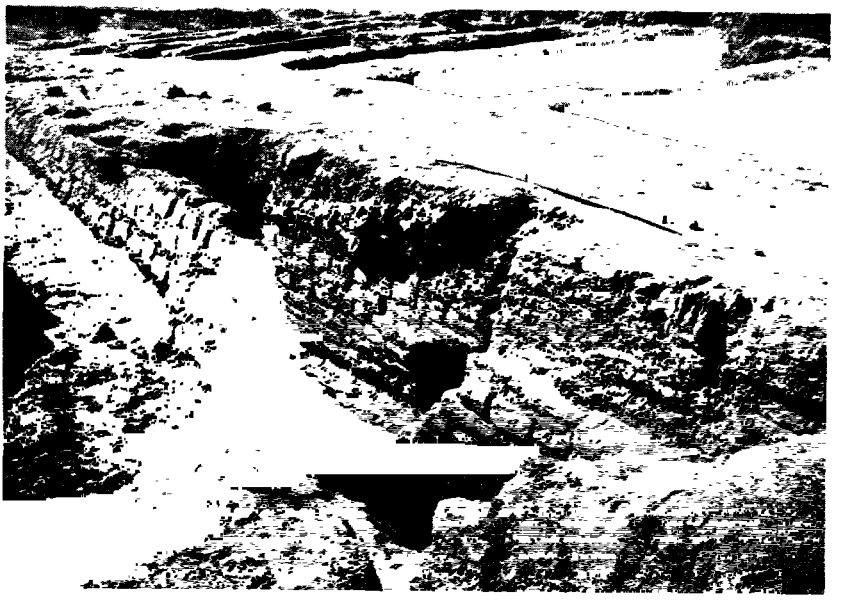


1. EXCAVATIONS AT TELL EL-KHELEIFEH LOOKING WEST-SOUTHWEST AT NORTHWEST END OF GULF OF 'AQABAH AND AT HILLS OF SINAI



2. REFINERY, EZION-GEBER

Outer south wall, showing two rows of flues.



1. Foundations of the larger (and inner) of the two outer fortification walls, with the glaçis built against it. The foundations of the perpendicular main wall were deeper than those of the sloping glaçis, which was bonded into the main wall about six or seven rows of bricks above its base.



2. Grave of man who may have been the builder of fortification walls.

EZION-GEBER.



1. ENTRANCE COMPLEX FROM NORTH.

Looking south through foundations of sea gateway of Ezion-Geber toward Gulf of 'Aqabah (eastern arm of Red Sea).



2. TELL EL-KHELEIFEH.

The first guardroom on the east side of the gateway. We have designated it Room 100A.



1. SEAL SIGNET RING OF JOTHAM, KING OF JUDAH, AND IMPRESSION OF INSCRIPTION ON SEAL.

Inscription reads LYTM, "belonging to Jotham." Underneath the inscription is a ram, with a man (?) standing by its head

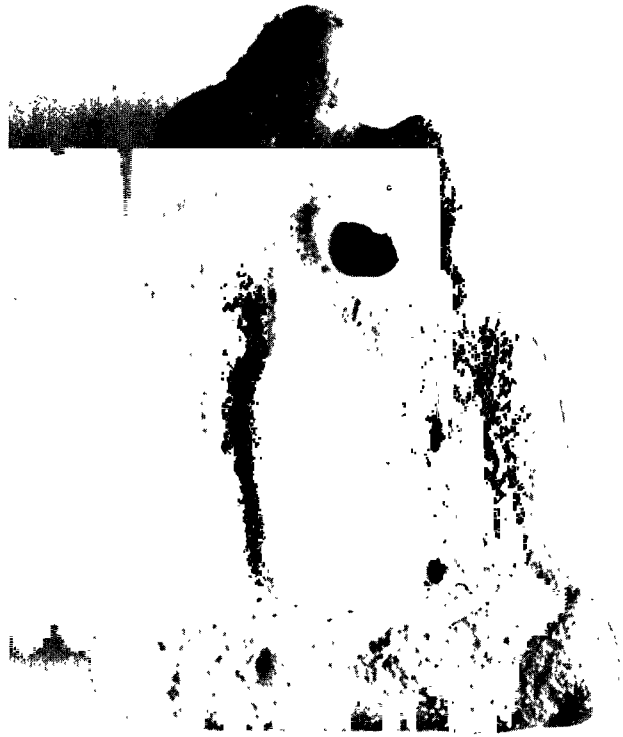


2. TYPE OF FINE JARS OF THIN GREENISH-GRAY WARE WITH QAUSANAL STAMPS ON THE HANDLES.

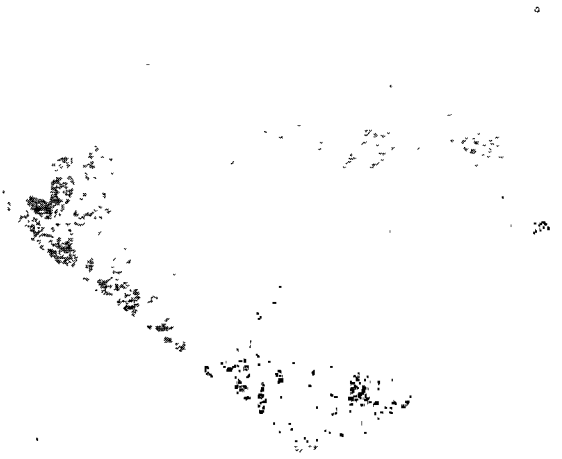
Such a stamp is visible at the bottom of the handle of the jar on the left



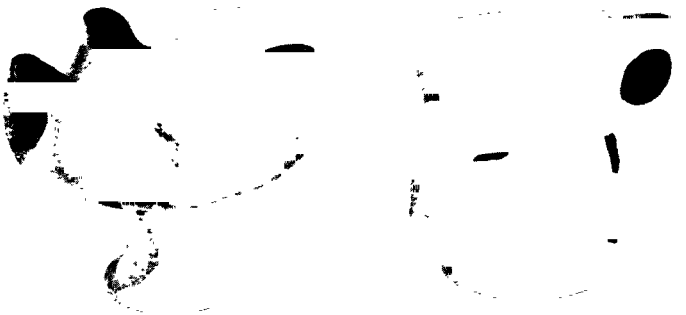
1. PARTLY RESTORED JAR WITH MINAEAN INSCRIPTION.



2. EGYPTIAN BUBASTITE CAT AMULET, ENLARGED 100 TIMES
22d dynasty, Shishak I.



1. ARAMAIC OSTRACON FROM FIFTH CENTURY B C LEVEL OF TELL EL-KHELEIFEH. IT IS A WINE RECEIPT. (FULL SIZE.)

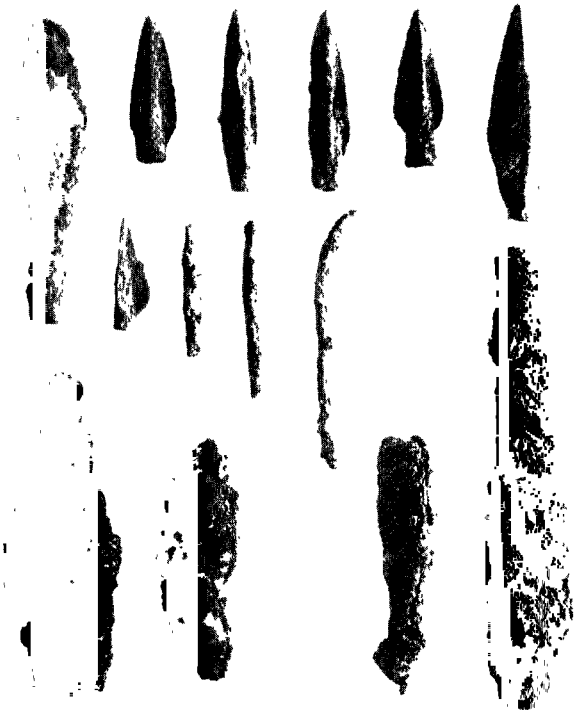


2. SEVEN-LIPPED OIL SAUCER LAMP AND POTTERY CENSER
(Approximately one third natural size.)



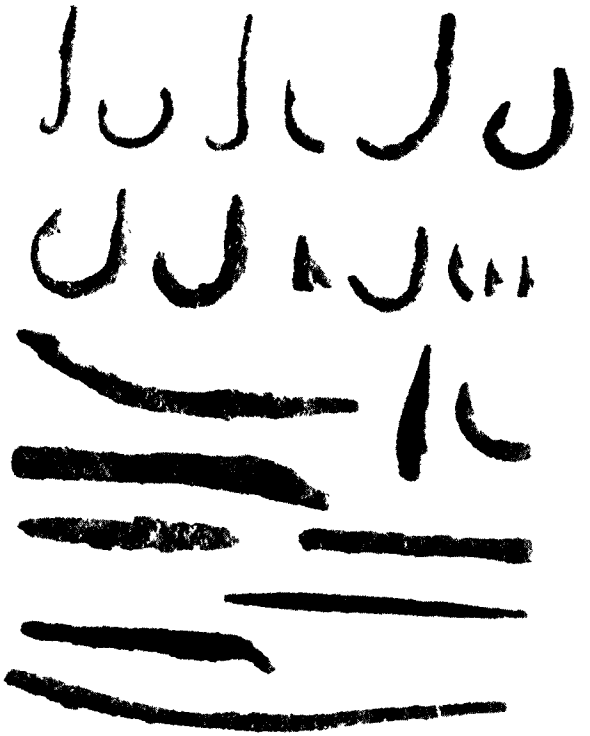
1 FRAGMENT OF GOLD EARRING AND BRONZE (COPPER) FIBULAE.

(Approximately one-half natural size.)



2. BRONZE (COPPER) ARROWHEADS, LANCE POINTS, AND TOOLS, AND IRON LANCE HEAD, KNIFE, AND HOOK IN BOTTOM ROW, FIRST THREE ON THE LEFT

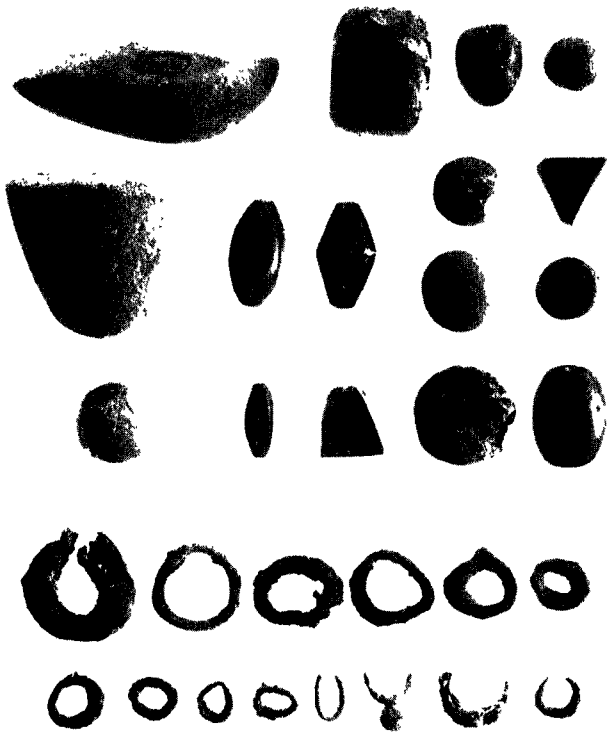
(Approximately one-half natural size.)



1. COPPER FISHHOOKS AND INSTRUMENTS
(Approximately one-half natural size.)



2. COPPER SPIKES.
(Approximately one-half natural size.)



1 STONE WEIGHTS AND BEAD BLANKS, AND BRONZE (COPPER) RINGS AND ORNAMENTS

(Approximately one-half natural size.)



2 STONE DRILLS, EXCEPT STONE AT RIGHT END OF SECOND ROW, WHICH IS PROBABLY A FISH-NET WEIGHT.

(Approximately one-third natural size.)



1. STONE MORTARS AND MILLS OF VARIOUS SIZES FOUND IN ONE ROOM



2 SIFTING THE DEBRIS IN A ROOM TO FIND THE SMALLEST OBJECTS IT MIGHT CONTAIN.



1 LARGE JAR FOUND IN POSITION SUNK INTO THE FLOOR OF THE ROOM TO KEEP THE WATER IT CONTAINED COOL



2. EIGHT-HANDLED, MARKED JAR FROM ELATH



'AQABAH LOOKING NORTHEAST AT MODERN FORT

DECIPHERMENT OF THE LINGUISTIC PORTION OF THE MAYA HIEROGLYPHS[1]

By BENJAMIN LEE WHORF

The Maya were the only fully literate people of the aboriginal American world. The buildings and monuments of stone that they left are covered with their writings—writings of which little has yet been read except the dates with which they begin. Moreover, they wrote many books and manuscripts, and three such books of fairly late period have been preserved. These are the famous three Maya codices, and I propose, before the end of this paper, to read a very brief extract from one of them, and to show, in a very plain and simple way, what the Maya writing system was like, and how its signs were put together.

Included in this writing system is a group of signs and combinations of signs referring to a special kind of subject matter. These are signs denoting numerals, periods of time, and terms of the calendar, between which mathematical relations exist and the use of which constitutes a system of mathematics. The mathematical references of these signs have been determined from these mathematical relations that are observed to exist between them, and thus we can read the dates and the positions of the solar-lunar calendar that are recorded at the beginning of most inscriptions. Besides this mathematical record, there is the purely linguistic portion of the writings, between the parts of which we can observe grammatical or linguistic relations, but no mathematical relations. These purely linguistic portions are those with which I shall deal. I shall deal, moreover, with the writing in the codices, not that of the inscriptions, though the inscriptional writing is generally similar to that of the codices. It may surprise many to know that in the codices the nonmathematical, linguistic signs outnumber the mathematical ones by more than a hundred to one (not counting repetitions of the same

[1] A paper read before the Section on Anthropological Sciences of the Eighth American Scientific Congress, Washington, D. C., May 10–18, 1940. Proof of this paper has not been read by the author, who died on July 26, 1941.

sign). So much for the belief that the Maya writings are mainly mathematical.

When Champollion began the decipherment of Egyptian writing, he was in the relatively fortunate position of not having to oppose an extensive body of established doctrine holding that the markings were not writing but a nonlinguistic symbolism. To be sure there were the fantastic speculations of Athanasius Kircher, concerned wholly with the religious and mystical symbolism which he read into the hieroglyphs, but these were upheld by none of the scholarly disciplines and quickly went down before Champollion's irrefutable logic. At that time the philologist and literary scholar reigned supreme in the study of ancient cultures. Champollion therefore had only to prove the linguistic logic of his results to philologists; he needed not to advocate his methods to archeologists, for there were none, except philologists. There was not then the specialized separation of disciplines which prevails now. At that time philology led the way, read inscriptions, and stimulated archeology.

It is popularly supposed that the success of Champollion's effort was wholly due to the discovery of the Rosetta Stone with its bilingual inscription, and that there is nothing corresponding to the Rosetta Stone in Maya hieroglyphs. Both suppositions are wrong. Champollion would have ultimately succeeded without a Rosetta Stone, for the inscriptions happened to be in a language that he knew. He knew Egyptian, that is Coptic, the late form of the language and still essentially the same tongue, which the ancient Egyptians spoke and wrote. Just so the Central American writings happen to be in a language that it is possible to know. They might have been in a dead language, and then the case would indeed be difficult, but fortunately they are in Maya, which is still spoken and can be studied from many sources. But how do we know they are in Maya? This will be quite clear to a linguistic scholar, who appreciates that if texts in an unknown character are in a language that he knows, it is likely that he can detect that fact from the the nature and frequency of repeated collocations of signs. In addition, the meaning of various clusters of signs in the Maya system is known from tradition (e. g., the glyphs of the months) and others from pictures that accompany them in the codices. The hieroglyphs record a language in which the writings for a certain month and for sitting position begin with the same sign, which is the image of a feather. This condition is satisfied only by the Maya language, in which the roots of these particular words and the root of the word "feather" all begin with the same syllable. Again, it is a language in which the writings for snake, fish, and a certain time period all begin with the same

or with mutually interchangeable signs, a condition also satisfied by Maya. It is a language in which the writings for honeybee, earth, and the name of a day begin the same, in which "hold in the hand" and "nothing" begin the same, in which "spear" and "noose" begin with the same sign, which is also found in the clusters that mean jaguar, nine, and lunar month, and so on. The evidence mounts and becomes at last overwhelming. Not even Cholti or Tzeltal, the languages closest to Maya, can satisfy the requirements; only Maya can do so.

There exists also a lesser equivalent of the Rosetta Stone, i. e., the preserved names of the ancient months and other calendar terms with the sign clusters for writing them, the ways of writing the numerals, the 27 characters recorded by Bishop Landa, the sign clusters for the cardinal directions, the colors, quite a number of animals, and various gods—a collection of odd bits that, when gathered together, make a not inconsiderable total. Finally there are many texts in the codices in which the meaning is almost as plain as though a translation ran beside it, because of the detailed pictures that run parallel with the text and illustrate it. Thus we really do have a Maya Rosetta Stone, as well as a knowledge of the language of the texts, so that, given linguistic scholarship like that of Champollion, it is perfectly feasible to decipher and translate some of the texts *now*, and eventually all of them.

But, on the other hand, the linguistic decipherer today has to contend with the chasm that now exists between American archeology and philology. The philological viewpoint, with its scholarly interest in texts simply as texts, has become rather strange and incomprehensible to modern American archeology, with its high development, along the scientific side, of the logical correlating of strictly material evidence, the while its popular side and its financing is largely connected with the esthetic interest, and with the interest that attaches to concrete human subject matter, particularly that of an exotic kind. Now the linguistic and philological interest is to be distinguished both from the materially and physically scientific interest and from the estheticohuman one; for while it is not entirely divorced from either, and it cannot live in a vacuum, yet it finds its main concern upon a different level, a level of its own. The linguistic scholar is interested in a text as the monument of a language arrested and preserved at a certain point of time. He is not primarily interested in the subject matter of the text, either as history, folklore, religion, astronomy, or whatnot, but in its linguistic form, which to him is the supreme interest of interests. From this proceeds his type of objectivity, an earnest that his reading

will not be affected by theories concerned with the content of the writing. He puts aside content to concentrate on linguistic form. He aims to reconstruct the language as it actually was, with its consonants and vowels in their actual places in words, its paradigms of declension and conjugation and its patterns of syntax, thereby adding a new body of facts to the whole domain of linguistic taxonomy. A byproduct of his research is the reading of history and culture, but it may be questioned if his discovery of strictly linguistic fact in a time perspective is not the more important. The decipherment of Hittite has proved to be far more important for the light it has thrown on the development of the Indo-European languages than for all the accounts of Hittite reigns and conquests. The battles and politics of the Hittites are as dead as a nail in Hector's coffin, but their verb forms and pronouns and common words are matters of live interest in American universities at this moment, since the accurate facts of the Hittite language revealed by careful decipherment are completely revolutionizing our concepts of Indo-European linguistics. This authoritative knowledge of Hittite could not have come about if the deciphering scholars had not been linguists who had slowly and carefully ascertained, by scholarly methods, with profound respect for the text as a text, the exact words and grammar, conceiving this as their paramount duty. It could not have come about if they had conceived their duty as that of reading off a sweeping survey of Hittite history and culture, or even as one of clothing the dry bones of archeology with the flesh of human narrative, important as these things are.

The desiderata for Maya decipherment are no different. Reading Maya texts must be a slow, careful investigation of linguistic forms, regardless of the interest or lack of interest of their subject matter. We must not conceive it our task to read off sweepingly the Maya literature for the sake of the information on history, culture, religion, or whatever else may be contained in it. The annals of this subject are cumbered by such attempts to read off or "interpret" the whole corpus of the Maya codices at one fell swoop, from Brasseur de Bourbourg to one very recent such an attempt. Such amusements proceed from a longing for glamour and quick results, misconceiving what is the most valuable thing to be obtained from the results. On the other hand much of the work of Cyrus Thomas, and various bits of linguistic data pointed out by Morley and others have been at least in the right direction—they seem to have understood what the problem really is.

The Maya writing system was a complex but very natural way—natural to minds just beginning to exploit the idea of fixing language in visual symbols—of using small picturelike signs to represent the sounds of fractions of utterances (usually of a syllable or less in

extent), combining these signs so that the combined fractions of utterance outlined the total utterance of a word or a sentence. Past study of this system has been considerably retarded by needless and sterile logomachy over whether the system, or whether any particular sign, should be called phonetic or ideographic. From a configurative linguistic standpoint there is no difference. "Ideographic" is an example of the so-called mentalistic terminology, which tells us nothing from a linguistic point of view. No kind of writing, no matter how crude or primitive, symbolizes ideas divorced from linguistic forms of expression. A symbol when standing alone may symbolize a "pure idea," but in order to represent an idea as one in a definite sequence of ideas it must become the symbol for a linguistic form or some fraction of a linguistic form. All writing systems, including the Chinese, symbolize simply linguistic utterances. As soon as enough symbols for utterances have been assembled to correspond uniquely to a plainly meaningful sequence (phrase or sentence, e. g.) in the language being written, that assembly of signs will inevitably convey the meaning of that linguistic sequence to the reader native to that language, no matter what each sign may symbolize in isolation. Meaning enters into writing, writing of any kind, only in this way, and in no other. The meaning of any linear or temporal succession of symbols is not the sum of any symbolisms or denotations that the symbols may have in isolation, but is the meaning of the total linguistic form which that succession suggests. Hence the fact that some individual signs look like pictures of the things or ideas denoted by the words of the utterance plays no real part in the reading; those signs are just as much symbolic, learned, and at bottom arbitrary signs for fractions of utterance as any other characters or letters. On the other hand, resemblance to an object or picture may be really important in decipherment, as a clue to how the sign came to be invented, to the logic of its original use, and hence to the fraction of utterance, i. e., sound, which answers to it in reading—a clue to be tested by how well that proposed fraction, or sound, fits into each proposed reading.

Figure 1 shows 23 symbols selected out of the several hundreds found in the whole Maya literature. These particular ones have been chosen because they enter into the written words and the codex sentence used as examples of decipherment in this paper. The fractions of utterance to which these signs regularly correspond have been identified by comparative evidence—running back ultimately to that body of evidence which I have called the Maya Rosetta Stone. Signs 1, 2, 3, 7, 8, 12, 17, 22, are also given by Landa with the same values (1, 7, 12, 17 being slightly altered in form) in his book "Relación de las Cosas de Yucatán," a first-hand account of the Maya shortly after the Conquest. The left-hand column shows in alpha-

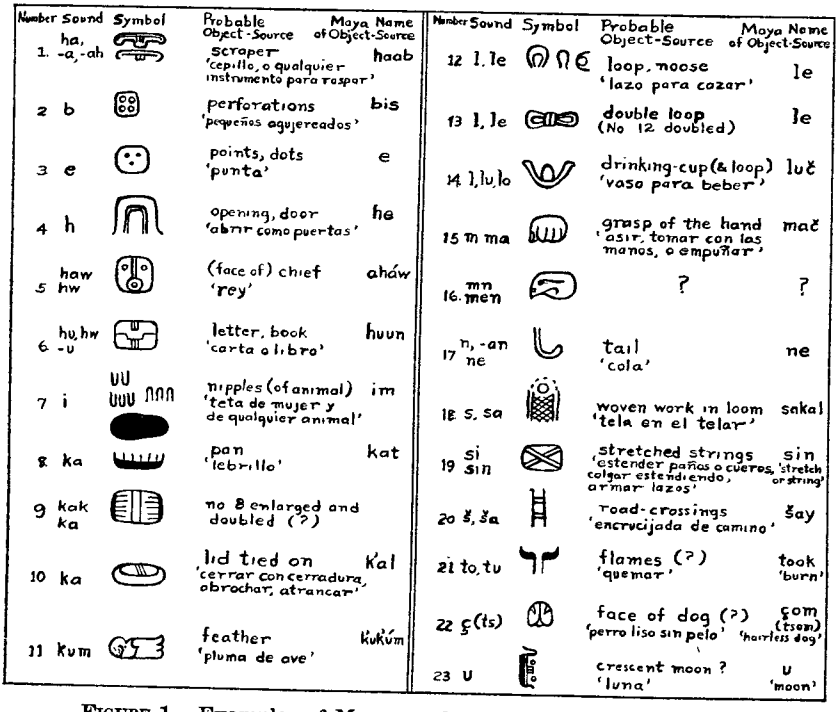


FIGURE 1.—Examples of Maya symbols having phonetic values.

betic order the fraction of utterance, i. e., sound which regularly[2] corresponds to the appearance of the sign in a written form. The next column to the right shows the usual appearance of the written sign, with common variants added in some cases. The list includes less than a third of all the signs the phonetic values of which I consider fairly well established. The column headed "Probable Object-Source" names the thing or condition of which the written sign was probably at one time a picture. However, these theories as to pictorial origins, while they seem probable and have a substantiating

[2] Regularly but not always in the case of all these signs, for polyphony is a prevalent trait in Maya writing, as it is also in Sumerian and Akkadian (Babylonian) cuneiform. That is, various signs are polyphones, with two or more contrasting sets of sound values, besides the slightly differing values within a set, such as either *ha* or *h* with vowel lacking or indefinite, which slight differences are on another level than the polyphonic contrasts. The native reader, able to grasp words as wholes, is not confused by these polyphonic values; he knows from the other signs assembled with the one in question just which of the polyphonic values applies in a given case, just as the reader of English is not confused by the *o* in *women* or the *olo* in *colonel*, but is governed by the total collocation so that he reacts with fractions of utterance entirely unlike those regularly associated with the written forms *o* and *olo*. Polyphony is therefore the same type of thing as irregular spelling under an alphabetic system of writing. Thus the Maya sign No. 5 of figure 1 has also the value *la, l*, as in the writing of the word *lak'in, lik'in* "east"; this value may very likely derive from the word *lalail* "the largest, greatest, principal, chief"—a near-synonym of *ahaw*. Sign No. 15 occasionally has the value *č*, as in the writing of *čik'in* "west"; this value probably derives from *čuk* "catch or seize with the hand," a near-synonym of *mač*.

value, are not the evidence for the phonetic values, and their being proved wrong would not invalidate the latter nor alter the readings; but would merely mean that the *origin* of the sign was other than I have supposed. There are several signs for which I am unable to offer any explanation (e.g., No. 16), yet for which the phonetic value is reasonably certain. I did not guess the probable object source of No. 6 until after I had known its phonetic value for several years.

The extreme right-hand column shows the Maya word, as given in the Motul dictionary,[3] for the thing or condition postulated as the object source. It will be observed that the initial sound of this Maya name of the object (i. e., the first consonant and/or the first consonant and vowel) is the sound which the sign represents in writing, as shown in the left-hand column, except in the case of No. 1, in which the initial *h* is either lost or transposed, yielding *a* or *ah*. The Spanish entry under the English name of the object source is the way in which the Motul dictionary defines the Maya word in the extreme right-hand column.

Figure 1 then should be self-explanatory. The following supplementary remarks may be added: No. 1 does not occur initially in a word. Primary word-initial *h* in Maya, in becoming secondarily word-internal, as when it begins the second member of a compound word, tends to be weakened or lost. This explains why a syllable originally denoting *ha* would denote *a* when used only to write non-initial fractions of words. No. 6 is especially interesting. Maya has simple, unanalyzable words for "write" or "book," not connected with "paint" or "draw" as in Aztec and many other American languages. This fact, ceteris paribus, argues for the greater antiquity of writing in the Maya culture than in these other cultures. Maya missives and books (e. g., the codices) were written on an elongated strip of tissue which was then folded up, and when tied or clasped would have an appearance not unlike a modern letter

[3] The Motul dictionary is an anonymous sixteenth-century work ascribed to Fray Antonio de Ciudad Real, and is the most voluminous and authentic source of information upon the Maya language at the time of the Conquest. Actually it is not only a dictionary but a grammar and a chrestomathy as well, for most of the word citations are accompanied by copious examples of phrases and sentences. The technique of stem-composition in Maya of this period is beautifully brought out in these examples; the same is true of syntax. The Maya words in fig. 1 are not cited in the conventional Maya orthography used in the Motul dictionary, but in the phonetic alphabet used by most present-day linguists for American Indian languages (the revised American Anthropological Association system), except that *ç* is used instead of *c* for the alveolar affricate (a sound like *ts*). The cedilla has been added to the *c* to avoid confusion with the *c* of Maya orthography which represents *k*. The symbol No. 22 is cited by Landa with the value *c;* it is unquestionable that he meant Spanish *ç* or the soft sound of *c*, as in the name of the letter *"ce,"* which is very likely what he asked his Maya informant to write. This soft sound of *c* was close to *ts* in old Spanish, which is why it was equated to the Maya sign for *ts*, No. 22. The sounds *č* and *š* are English *ch* and *sh*, *k'* is a glottalized *k;* the language has a series of such glottalized sounds: *p'*, *t'*, *č'*, *ç'*, *k'*. Through some curious omission, the Motul dictionary does not actually cite the word *ne*, "tail," but this is, of course, a well-known Maya word.

sealed in its envelope, or like No. 6.[4] The nipple (*im*) sign for *i* appears in the codices usually with three nipples, which leads me to think that the teats of a deer or other animal may have been one of the original forms; sometimes it appears with two; Landa shows it with two, and the sign of the day Ik (*ik'*) may be based on an original human breast form with only one. No. 8 probably represents a *kat*, an earthen, basketry, or wooden pan, tray, or low flat tub, often boat-shaped; it was also called a čem or boat (see Motul, *chem licil ppo* and *chem che*), and conversely a boat may have been called a *kat*. The comblike lines may be the conventionalization of a fluted rim or of projecting basketry withes, or may represent people in a *kat* in the meaning boat. No. 10 is an example of the many perspective drawings found in both Maya art and the writing symbols—a rounded, flattened pot, basket, or calabash with a *k'al*, a tied-on or clasped lid or cover. The Maya, as is well known, drew in perspective from very early times. No. 11 is a *k'uk'úm*, feather or plume, and in this word *k'úm* was probably felt to be the true initial form of the stem and *k'u-* a reduplication, which may not have been historically the case, but which would be felt analogically in a language like Maya in which initial reduplication is a derivational process in wide use. Nothing as yet is postulated as to the object source of 16, a profile head with a sort of parrotlike beak; a suggestion here would be the parrotlike bird called *moan* or *muan*. The sign corresponds to the consonantal sequence *mn*, with any or no vowel intervening, and as a day sign denotes the day Men. No. 23 looks very much like a form of No. 1, but it is always upright and placed in front of a sign cluster with its concave side toward the cluster, while No. 1 is not placed in front of a cluster and is usually horizontal. No. 23 corresponds to initial *u* of a word or to *u* as a separate word or as a prefix.

[4] As may be inferred from this, I regard the previous theories about what No. 6 represents, one of which calls it a kernel of maize (to which it has no resemblance), as fanciful. The fact that in some Maya pictures corn plants may sprout from characters of writing, and characters may take part in the scenes like persons or objects, is secondary symbolism, not the original logic from which the character arose. All this elaborate secondary symbolism, perhaps religious and magical in large degree, has nothing whatever to do with the reading of the characters in their capacity of symbols of writing, any more than the elaborate symbolism and numerology that grew up around the Hebrew letters in rabbinical tradition affects the reading of the Hebrew texts by one jot. This secondary symbolism may eventually become a matter of philological literary study, wherein it will very likely prove important. At present, and from a linguistic standpoint, clearing away all this sort of symbolism is essential to understanding the proper symbolism and function of the Maya signs in writing. The use of No. 6 to denote the day Kan is a writing of the original name of the day Hu—i. e., lizard, iguana (cf. Aztec Cuetzpalin, lizard, for the same day). All the original names of the days, except for Ik, Cimi, Caban, and perhaps Manik, Cauac, and Eznab, and one or two more, became changed under the Maya culture subsequently to the establishment of the writing system. Some of the days continued to be represented by the initial letter or character of their original names, much as we write "lb." for "libra," but read it "pound." The voluminous speculations of Seler concerning the day symbols are to be taken with a great deal of caution, if they are not indeed stumbling blocks of the worst kind.

Figure 2 shows the writing of six words occurring in the codices.[5] The sign clusters or glyphs of various animals, originally determined by Schellhas from their concurrence with pictures, have long been known.[6] No. 1 is cited by Schellhas as the glyph meaning snake. It will be noted that it consists of No. 8 of figure 1, *ka*, and No. 17, *n*, and a third symbol. This third symbol and the iguana figure in the next glyph of figure 2 are the only symbols cited in this paper which are not found in figure 1. The first two symbols spell *kan*, which is the Maya word for snake. The third symbol is probably

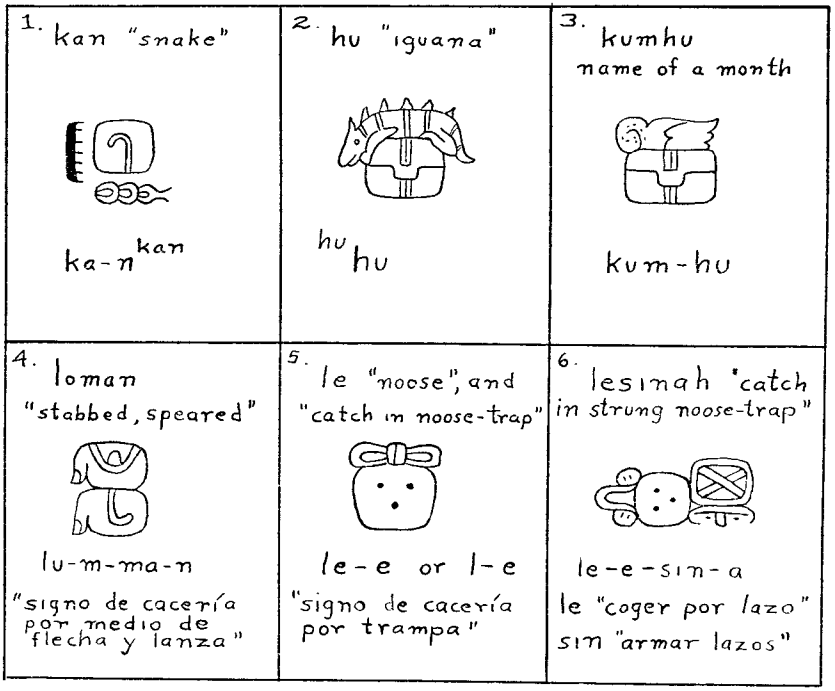


FIGURE 2.—Maya sign clusters representing words.

derived from a picture of a rattlesnake's rattles, intended to evoke the linguistic response "snake," i. e., *kan*, and has itself the value *kan*. However, it is apparently insufficient by itself to write the word *kan*. It was not unusual in the Maya system to write a word of one syllable simply by one sign having the value of that syllable, probably because that sign often was polyphonic, having other values. Instead, the Maya method was to suggest the syllable by a combination of signs that was probably, to Maya speakers acquainted with the conventions of the writing, unambiguous. This combination of signs

[5] In an unpublished paper read before the annual meeting of the American Anthropological Association at Washington, D. C., in December 1936, entitled "A Comparative Decipherment of Forty-Six Maya Written Words," I exhibited 46 word-writings similarly analyzed, including *hu* and *kumhu* of the present six.

[6] Paul Schellhas, Göttergestalten der Mayahandschriften, 1897.

could be made according to two principles: (1) synthetically, building the syllable from signs to be understood as fractions of the syllable, which together made the whole syllable; (2) by repeated affirmation, that is, by combining, in the sense of repeating, different ways of denoting the whole syllable. A word of one syllable, or often a syllable within a longer word, could be written by either method, or by both together, as in the case of this writing of the word *kan*. The signs *ka* and *n* build the word synthetically, the sign *kan* repeats it; we have double writing, but only single reading. It is as if the writing said "my first is *ka*, my second is *n*, my whole is one of the values of the snake-rattle sign, and so must be *kan*." The combination is, by sum of all its parts, *ka-n-kan*, but we may use the convention of transliteration *ka-n*$^{-kan}$ to show that the final *kan* is a doubling in the writing only, not in the reading.

No. 2, figure 2, is the sign cluster meaning iguana, or large lizard, a meaning which is quite obvious since it accompanies plain pictures of that animal, besides containing such a picture itself. But this one picturelike sign, no matter how much it may look like the animal, is not sufficient by itself to write the word meaning iguana. The Maya system, as already noted, requires combination with at least one other sign before we can have a unit of writing, capable of standing alone. The exceptions to this rule form a very restricted list indeed, the most important ones being the 20-day signs, which are single elements enlarged to the size of a full cluster and capable of standing alone. The month glyphs and calendric and mathematical glyphs in general conform quite to the rule, being clusters of signs. No. 2 writes the one-syllable word *hu* "iguana" entirely by the method of repeated affirmation, using the ordinary sign for *hu*, No. 6 of figure 1, topped by an iguana figure, which of course has the linguistic value of the animal's name. Here the formula which we use in transliterating is *hu-hu*, to be read or pronounced, of course, as "*hu*."

No. 3 writes the word *kumhu*, the name of a Maya month, entirely by the synthetic method. It is the well-known glyph of this month Cumhu as found in the codices. It uses the feather sign *kum*, No. 11 of figure 1, plus *hu*, No. 6, so we transliterate *kum-hu*. Some other words of the codices using the sign *kum*, No. 11 of figure 1, are *kumah*, the stem "sit" with transitive suffix meaning "seats" or "carries seated," and *kumaç*, another word meaning snake (cf. Quiche *kumaç* "snake"). Although we are still somewhat in doubt as to the values of the vowels in these words, the general phonetic contour is interestingly confirmed by the fact that the codices write *kumah* not only as *kum-ma* (with 11 and 15) but also write it as *kw-m-a*, while Landa cites a way of writing the month Cumhu which is the cluster of *kw-m-hw;* in both of which writings *kw* and *m* are signs

not included in figure 1 (but confirmed by other evidence) while *a* is 1 and *hw* is 5 of figure 1.

No. 4 of figure 2 occurs in texts of the Codex Tro-Cortesianus dealing with hunting and illustrated with hunting pictures. It is obviously a sign cluster or word referring to animals killed by spears or arrows, and the commentary in the Villacorta edition [7] of the Tro-Cortesianus calls it "signo de cacería por medio de flecha y lanza." It is a writing composed synthetically with doubling of one subsyllabic sign. At the top is the cup-and-loop sign *lu, lo*, No. 14 of figure 1, written within the outlines of No. 15, *m, ma*, which is doubled, the lower member of the doubled pair enclosing the tail sign *n*, No. 17 of figure 1. When we find doubled a sign which according to the total set-up is probably to be interpreted as a syllabic confirmed by a subsyllabic, we may transliterate without using the convention of writing a superscript, using instead a convention that permits of possible interpretation as a long consonant or vowel, e. g., in this case not *ma-ma* but *m-ma*. No. 4 is then transliterated *lu-m-ma-n* or *lo-m-ma-n*, which is a word meaning exactly what the accompaniment of pictured scenes tells us. It is the passive participial inflection in *-an* of the stem *lom*, which means a spearing or stabbing thrust or blow, and by extension a spear, while with the verbal inflection it denotes the occurrence of a spearing action. The Motul dictionary gives "*lom*: tiro de lanza, o dardo, y cosas assi, y estocada, o puñalada." This stem with the transitive verbal inflection is given by the Motul as "*lomah, ob*: fisgar, o harponear, dar estocada o puñalada, alancear y aguijonear," this citation being followed by that of the passive participial form, "*lomán*: cosa que esta assi fisgada." Hence this word *loman* written in the hieroglyphs of the Maya text means speared, stabbed; pierced, wounded or killed by a spear, arrow, etc.

No. 5 of figure 2 is synthetic with doubling of the inherent vowel of one sign. It is common in the hunting section of the Codex Tro-Cortesianus, and is obviously the word denoting catching of animals by a noose or lasso, or in a noose snare—a trap consisting of a noose set to spring by a stretched rope triggered and attached to a small bent-down tree so that when the animal steps in the noose and releases the trigger the tree springs back, drawing the slipknot of the noose and catching the animal. The glyph or sign cluster No. 5 accompanies pictures of this operation, e. g., Tro-Cortesianus 42c. Villacorta calls it "signo de cacería por trampa." It consists of the double loop or knot sign *l, le*, No. 13 of figure 1, and the dot sign *e*, No. 3 of figure 1, and is to be transliterated *le-e* and read *le* "loop. noose, slipknot, noose trap or snare," Motul "*le*: lazo para cazar y

[7] J. Antonio Villacorta C. and Carlos A. Villacorta, Códices Mayas, published in Arqueología Guatemalteca, 1932.

pescar, y pescar con lazo," with the verbal inflection, e. g., *leah* meaning catch or trap with noose snare, for which the Motul gives the participial "*lean*: cosa enlazada o cogida en lazo." Here again we see the principle that a sign is inadequate by itself, in that No. 13, though itself derived from the picture of a slipknot or noose *le* and denoting the sound fraction *le*, is not sufficient alone to write the monosyllabic word having this sound, i. e., *le* "noose," but is subject to the rule that a sign must be combined with another and cannot stand alone. Here it has its inherent vowel reaffirmed by attachment of the sign *e*. Hence there is a mixture of the synthetic and the repeated affirmation principles in sign clusters or glyphs of this type. We also find the verbally inflected form *leah* "catch with noose," written *le-e-a*, with No. 1 of figure 1 for *a*. Cyrus Thomas correctly analyzed the *le-e* cluster, I believe, though I worked it out without referring to his work. A number of Thomas's readings are undoubtedly correct.

In No. 6, figure 2, we have one of the polysynthetic words common in Maya, in which two stems are compounded and suffixes attached. It is illustrated in Tro-Cortesianus, page 46, by three pictures showing vividly in successive stages of action a deer caught and jerked upward by the spring of the bent tree to which the noose of the trap is attached. It is written *le-e-sin-a* (or *-ah*), with signs 12, 3, 19, and 1 of figure 1, and is to be read *lesinah*. This word is typical of a common kind of Maya compound, consisting of two stems with the verbal inflection suffixed after the second. The stems are *le*, already defined, and *sin* "stretch or string tightly (as cloth, hides, or cords are stretched on a frame), draw taut, string with stretched cords, string up, string or rig a noose trap or the like to spring when released, etc." The Motul gives "*zin* (i. e., *sin*): estender paños o cueros y colgar estendiendo o tender desarrugando; armar lazos; armar arco o ballesta." Such a compound usually has the following type of meaning: designating the two stems as X and Y, a compound X-Y-*ah or* X-Y-*t-ah*[8] means do X by means of Y, transitively, or to an object. Thus, since *le-ah* means catch in a noose, we can form freely words such as *le-k'ab-ah* (or more modern *le-k'ab-t-ah*) "catch in a noose by action of the hand" (*k'ab* "hand"), *le-k'as-ah* "catch in a noose by a tying action," and so on. Our word *le-sin-ah* then means catch in a noose by the action *sin* or catch in a noose by tight stretching, catch by the spring of a tautly strung noose trap.[9]

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[8] The form with the suffix *-t-* before the suffix *-ah* is the common form in Maya of the Motul dictionary for binary compounds of this type.

[9] We find in the codices other compounds of this type, including some others with *sin* as second member; thus in the Tro-Cortesianus (e. g., 41a) the picture of a deer trussed up in a bundle, legs folded up, with cords lashed around it, is accompanied by the sign cluster *ma-sin-a* (with Landa's *ma* sign), to be read probably *massinah*, assimilated from *mačinah* compound of stems *mač* and *sin*), meaning clasp together (like a clasped fist) by pulling and tension, by tight stringing, by tightly drawn cords.

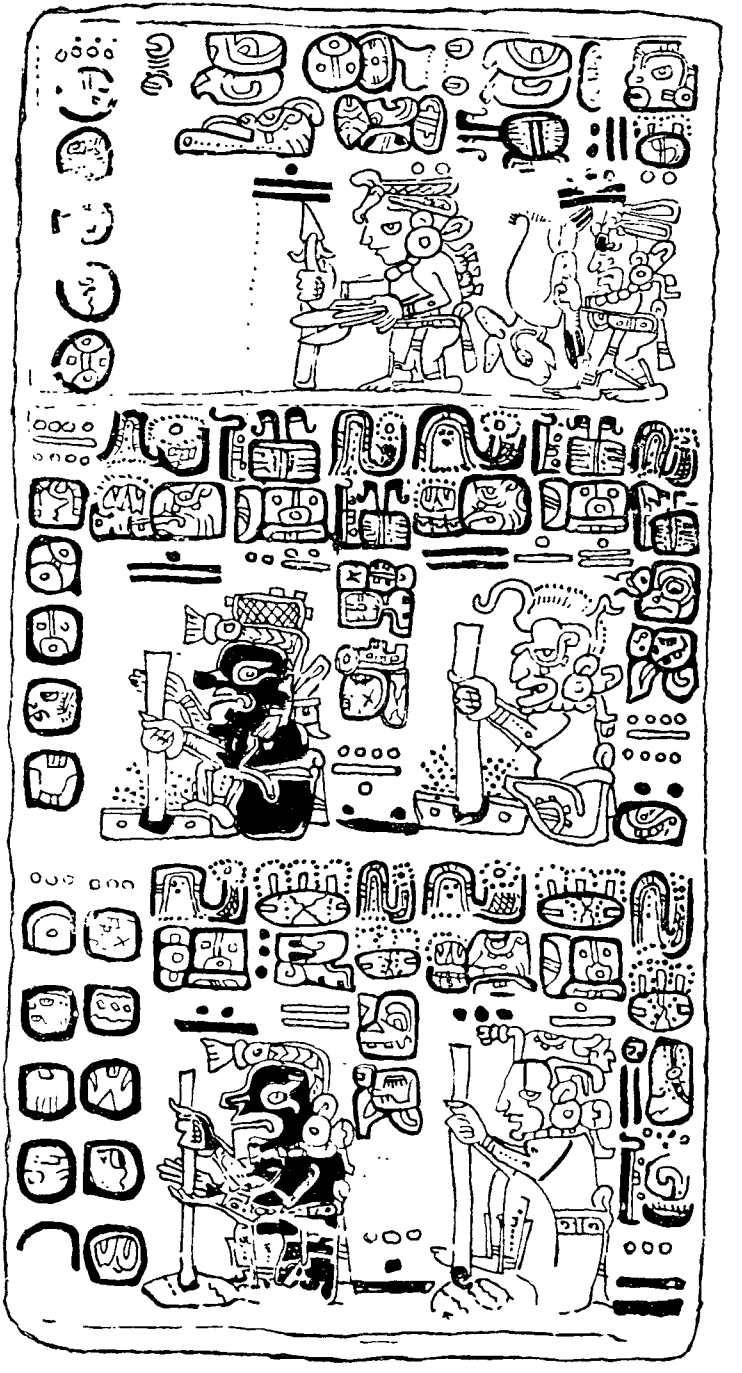


FIGURE 3.—Page 38 of the Codex Tro-Cortesianus.

Now, having noted the reading of a few individual words, let us read a short sentence written in Maya hieroglyphs. Figure 3 shows page 38 of the Codex Tro-Cortesianus, and the sentence thereon to be examined in particular is that made by the four sign clusters or glyphs over the second seated figure in section b, the middle of the three horizontal divisions of the page. Figure 4 shows this sentence written on one line, analyzed, transliterated, and translated. As can easily be observed from figure 3, the texts which comment on the pictures, or to put it the other way, which are illustrated by the pictures, are placed over the pictures reading from right to left across the width of the picture and then on the line below similarly; or they run vertically downward in the cases where there is no picture. This order is easily demonstrated from the parallelism of the writing; we have here plainly a repetition of very similar short sentences or clauses. Thus, if we give a letter to each cluster or glyph which is the same, the middle-section text over the first or left-hand picture runs A–B, and then on the line below C–D, next to the right running straight downward we have A–B–E–F, then over the next picture A–B–C–D again, then downward again A–B–G–H. The texts of the top and bottom sections can be seen to run in the same manner, which indeed is general throughout the codices. The texts would seem to be in a style which is common enough in aboriginal American songs, chants, and ceremonies; sets of phrases containing a constant element repeated throughout a set, as when each line of a song stanza begins the same way but then introduces a certain difference. Thus the text which we have just examined consists of lines each beginning A–B and then becoming different. Navaho chants are of course typical cases of this sort of thing. In the top section, dealing, as the pictures show, with hunting by means of the spear, each clause begins with the word *loman* "speared" that we have already studied. We shall not however pause to analyze this top section in detail, since the limits of this paper do not allow it.

The middle and bottom sections are very similar to each other, though not identical, and deal with drilling, as can be seen from the pictures. The pictures of the middle section show the using of the drill to make fire, the bottom set show the drilling of an object which appears to be a stone. Each clause in each section begins with the word for drilling or drill, as is evident not only from comparison with these pictures, but also from one of the other Maya books, the Dresden Codex, in which the same sign cluster accompanies pictures of drilling. This cluster, A, occupies first position, which is the regular position of the predicating word of a clause in Maya of the sixteenth century (if not also today) as shown by the hundreds of short simple sentences in the Motul dictionary. This predicator

need not be a formal verb in Maya grammar (though it most often is), but it is what corresponds to the predicate in an English translation. The final two words of each clause, C, D, * * * etc., are the well-known name glyphs of the Maya gods. They are the names of the persons shown in the pictures, as has long been known, and consequently they are undoubtedly the grammatical subjects of the clauses. The second cluster of each clause may be called B_1 in the middle section, B_2 in the bottom section, to indicate that it is the same throughout each section but differs between the two sections.

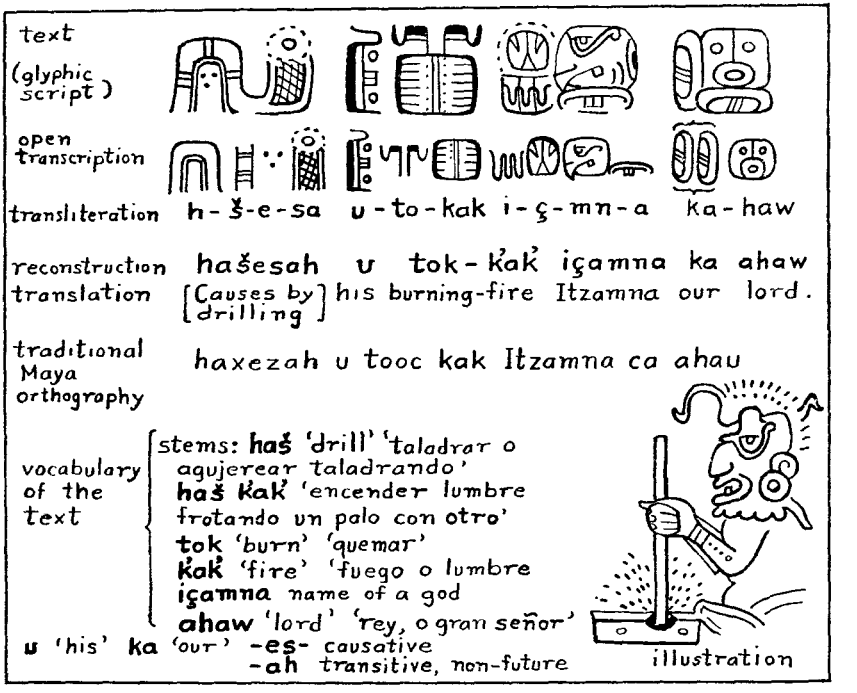


FIGURE 4.—Analysis of a Maya sentence taken from page 38 of the Codex Tro-Cortesianus.

By elimination and by position after the predicator it should indicate the grammatical object and/or result of the verb action, which agrees with the fact that the drilling is pictured with different objects and results in the two sections. Thus we have, as a first schematization:

A, predicator or verb (drilling)
B_1, B_2, object and/or result (fire, stone)
C, D, * * * etc., subject (names of gods or persons)

Figure 4 is a detailed exposition of the sentence over the second picture of the middle section, which shows the Roman-nosed god of the codices, or god D, making fire with a drill. The top line is a copy of the text, arranged from left to right on one line, instead of on two lines as in the original. This line, like the original text, is

in glyphic script, the form of writing used in the codices. It closely resembles the monumental glyphic style of the stone inscriptions, but is less ornate and has more rounded outlines. In both these styles the signs in a cluster are gathered into a tight bunch or cartouche, in which they are grouped in two dimensions and there is only a vestige of linear order in that the front or extreme left-hand part of a cluster never stands for the last part of a word and similarly for the rear or right-hand part, which never stands for the beginning of a word. The signs in a cluster are usually in contact and often fused together or enveloped in the same flowing outline; they may be attached to the top or bottom of a central sign or they may be one within another, i. e., one sign may serve as the frame or ground of another. In short, the putting together of signs is more like that of a heraldic device than like our kind of writing.[10] But the reading of the signs is exactly as if they were written in linear order, although this order must be learned separately for each glyph and hence requires a separate and often prolonged study of each by the decipherer.

The second line from the top in figure 4 shows the signs which compose each cluster regrouped in one-dimensional linear order. Such an arrangement I call open transcription or linear script, and there is some evidence that the Maya actually used such a form of script, though not in the inscriptions or in the codices that happen to have been preserved. Landa cites instances of the utterances "*ma in k'ati*" and "*elele*" written by a native informant in this manner,[11] the signs delineated consecutively from left to right and either close together or actually touching. It seems not unlikely that such a linear script may have been used by the later Maya for convenience in ordinary purposes, as the Egyptians used demotic, while the glyphic script would have been regarded as more hieratic and ornamental and used for important books, priestly writings, and inscriptions. Be that as it may, conversion of a passage of glyphic into open transcription is a device which is often helpful to the decipherer. It will be noted that all the signs in this passage are given in figure 1, so that from this line of open transcription the whole utterance

[10] It should be pointed out that even in our kind of writing, i. e., the alphabetic kind, linear order of signs is not quite absolute in many systems, which contain vestiges of an older two-dimensional way of grouping. Thus in the writing of pointed Arabic, pointed Hebrew, and Pitman shorthand, the vowel points are grouped two-dimensionally with the consonantal signs, not written consecutively with them in the order of actual utterance. In the Devanagari alphabet the vowel signs are fused two-dimensionally with the consonant signs, and the vowel *i* to be uttered after a consonant is actually attached in front of that consonant. Our own *wh* is similarly written backward, being actually *hw*—a special cluster of signs that retains an unusual order of positions. Some monograms and modern advertising placards also use two-dimensional groupings of letters.

[11] Diego de Landa, Relación de las Cosas de Yucatán. The first phrase means "I do not want." The second utterance is gibberish from the Maya standpoint, but judging from the context it evidently represents the informant's attempt to comply with a request to "write L-E, *'le'*."

can be read off in rough outline, as shown in the third line or transliteration. Since many of the signs can be indefinite as to vocalic timbre, even when they imply a preferred inherent vowel, the vowels of the utterance are here and there doubtful, although the indication of definite vowels is generally much better than in Egyptian or unpointed Hebrew. To a certain extent, but by no means wholly, the transliteration of vowels is based on sixteenth-century Maya, which can hardly have changed radically in this respect since the period of the codices probably not very many centuries earlier; and it is also based partly on comparative evidence from other Mayan dialects, a field of research which must of course go hand in hand with scholarly and philological reading of the codices. But it must also be emphasized that the text itself contains unmistakable reference to many of its vowels; thus the signs *a*, *e*, *i*, *u* of figure 1 are unambiguous in their indication of vowels, though the position of the vowel in the word may not always be clear. Thus we arrive at the transliteration, namely:

h-š-e-sa u-to-kak i-ç-mn-a k-ka-haw

The position of the *e* in the first word is not wholly clear, since this *e* is written inside both the *h* and the *s* signs; and another possible transliteration is *h-e-š-sa* or *he-e-š-sa*, to be read either *hešesah* or *hešsah*, which would indicate that the stem which means drilling, which is *haš* in sixteenth-century Maya, was pronounced more nearly *heš* in the dialect of the codices. At present more evidence would be needed to confirm this, and the reading *hašesah* seems preferable, the vowel *a* not being indicated in the writing but a reasonable reconstruction from Maya linguistic evidence.

Under the transliteration is a reconstruction of the original sentence in the light of Maya linguistics, written in the usual Americanist phonetic system, and below the translation of this is a repetition of the reconstruction written in the traditional Maya orthography. This is included in order that Maya students may see the sentence written in the way most familiar to them; though the use of this traditional spelling for linguistic purposes is not to be recommended and imposes a handicap; indeed may breed quite misleading notions in the minds of students. Thus we have for the reconstruction:

Phonetic—— *hašesah u-to·k-k'ak' içamma ka-ahaw*
Traditional—— *haxezah u tooc kak Itzamna ca ahau*

Under the phonetic transcription is the literal translation: "makes (or made) by drilling his burning-fire Itzmna our lord," or in smoother English: "Our lord Itzamna kindles (kindled) his fire with a drill."

The first word is a derivative of the stem *haš* meaning twisting or rolling between the palms, drilling, and with the verbal inflection,

twist between the palms, work a drill, bore, drill. The Motul has "*hax, ah, ab* (i. e. *haš, kašah, hašab*) : torcer con la palma o palmas de las manos y hazer tomiza, o cordel assi, y lo assi torcido" and again "*haxs:* taladrar o agujerar taladrando y la cosa taladrada o agujerada assi." This stem is the only word for drilling in Maya that I know of, so the case is particularly convincing. The word for a drill, the instrument, is *hašab;* we do not have it in this codex, but rather the verbal inflection. The suffix *-es, -s* (followed by *-ah*) of the verbal inflection is causative, similar in meaning to the suffix *-bes; X-es-ah* means puts (put) it (grammatical object) into the condition X, or else, cause (caused) it to exist by the condition or action X, makes (made) it by X-ing, by doing X. The second type of causative meaning is that which fits the present case. The suffix *-ah* denotes transitive action already accomplished, in contrast with *-ik*, transitive action not accomplished or not finished, either future or continuing in the present. Thus *hašesah* means makes (made) it by drilling.

Makes what by drilling? According to our scheme above, that which is denoted by the next sign cluster, B_1. In the bottom section of the same page the corresponding cluster B_2 denotes the stone or stone object being drilled. In that case "makes by drilling" of course does not mean create the object wholly by drilling, but rather perform that step in the manufacture of the object that requires drilling. Hence in that case there is merely a subtle shade of difference between *hašesah* and *hašah* "drills it." To digress a little, cluster B_2 is probably to be read *e-i-l-l: e*, dots, here many instead of three, *i* of three nipples, and a form of double-loop *l* doubled by scratches (*lač*) between the loops. The word *eil* could mean edge-tool, i. e., weapon-point, knife, etc. Such points or knives were of course predominantly of stone among the Maya, and were no doubt sometimes drilled.

Returning to the middle-section text; here "*hašesah* B_1" means makes B_1 by drilling, actually in the sense of "causes" or "creates," since B_1 evidently denotes fire. This fits in well with the expression cited by the Motul for making fire with the firedrill: *hašah k' ak'* (*k'ak'* "fire"), which uses the simpler or less inflected form *hašah* rather than *hašesah*. The Motul gives "*hax kak* (i. e., *haš-*[*ah*] *k' ak'*) : encender lumbre casando fuego frotando un palo con otro," also "*haxab kak* (*hašab k' ak'* 'drill for fire') : artificio o recaudo con que sacan fuego los indios."

The cluster B_1 is analyzed as *u-to-kak*, consisting of sign No. 23 of figure 1, *u*, sign No. 21, *to*, *tu* (to be read here *to*), and No. 9 of figure 1, which if it is a doubled and enlarged *ka* (No. 8) might be read *kaka*, *kak*, or simply *ka*. Here the reading *kak* fits exactly. The initial *u* here would denote the preposed third-person pronominal reference *u*. For our present purposes it is immaterial whether this

be regarded as a prefix or a separate word always occurring immediately before nonpronominal stems. Owing wholly to the grammatical patterns of English (and other European languages), it must be translated as *he* (*she*, *it*, *they*) if the following stem is translated as an English verb, but as *his* (*her*, *its*, *their*) if that stem is translated as an English noun. From the Maya standpoint it denotes the same relationship at all times; Maya stems are neither nouns nor verbs in the English sense, but a single class delimited on a quite different basis from our parts of speech. The stem with which this *u* is in construction is what is written as *to-kak* in the rest of the cluster.

The writing *to-kak* however is only approximately phonetic, as with Maya writing in general; it suggests only in rough outline the sound of the utterance, from which suggestion the reader is expected to infer the right Maya word; the Maya application of phonetics in writing had progressed no farther than this, as we have already seen. Now the word that is apparently indicated is not what a modern Americanist phonetician understands by the transcription *tokak*, but rather what he would transcribe as *to·kk' ak'*. This is a compound word, *to k-k' ak'*, consisting of the stems *to k* "burn, burning, ignition" (*o* denotes long *o*) and *k' ak'* "fire." The Motul gives these as "*tooc* (i. e., *to ·k*) : quemar, abrazar, y cosa quemada" and "*kak* (i. e., *k' ak'*) : fuego, o lumbre." Note that the Maya way of writing *to · kk' ak'* does not distinguish the glottalized palatal stop *k'* at the end of *k' ak'* from the corresponding unglottalized stop *k* at the end of *to · k*, nor does it distinguish the sequence of the two, *kk'* from either one singly nor the long vowel *o* from a short *o*. This is all part and parcel of the approximate and outlinelike character of the phoneticism, implicit rather than clearly conscious phoneticism, which Maya scribes employed. There is a phonemic difference between the simple and the glottalized stops in Maya but it is a minimal difference. The writing used the same symbol for both a simple stop and the homorganic glottalized stop; instances of this are numerous. This does not mean that these were not distinct sounds in the Maya dialect of the codices. It is almost a certainty that they were distinct, just as they are in all modern dialects of Maya. They were not distinguished in writing probably in the same way that minimally-differing phonemes (e. g., the long and short vowels of Latin) are often not distinguished in a writing system, because the native reader can always tell from the context which sound to supply. And this condition is no more than we meet, to varying degree, in all systems of writing other than those devised by linguistic scientists for the express purpose of an accuracy going beyond the needs of simple communication.

The expression *u-to · k-k'ak'* may be translated "his burning fire," or probably better "his kindling fire, his igniting of fire." It follows

a type of Maya two-stem compound, probably the same type as already explained, though the idea of "by means of" here need not be injected into the translation. We now have attained to translation of the whole predicate: "(he) causes by drilling his ignition of fire; and it is evident that this expression *ha esah u-to·k-k'ak* is but a more elaborate form of the *hašah k'ak'* cited by the Motul dictionary as the way of saying that one starts fire with a fire drill; it follows the same basic pattern.

I might here digress briefly, anticipating a misconceived objection that might be raised, to say that the sign cluster *to-kak* sometimes occurs in the codices where there is no pictured reference to fire, and seems in these cases to refer to an animal in a hunting scene. An instance of this is seen in figure 3, top section, over the second picture, where occurs the cluster *to-kak-a*, with *-a* of No. 1, figure 1, and without preceding *u-*, forming part of a sentence roughly analyzeable as *loman u-NORTH tokaka X* "speared (in) his north (is) (grammat. object)–X." I shall suggest first, but not in seriousness, a type of explanation that overstresses the mentalistic approach. I shall suggest that the reason why this glyph accompanies both pictures of fire and pictures of a hunted animal is that it is a glyph which denotes sacrifice or a sacrifice, hence either a sacrificial fire or a sacrificial animal. Now apparently just this sort of explanation, with its thin veneer of ethnological allusion, sounds plausible to some minds that have engaged themselves with Maya hieroglyphs, and it is necessary to warn against it. This is why no people but linguists should touch the hieroglyphs. In the present case of course, the explanation is an out-and-out concoction of my own, cooked up in a few seconds merely to illustrate a point. A trained linguist would, I believe, be inclined to ask, "Have you searched for an explanation in the configurations of utterances and in the data of the vocabulary, before adopting this quite speculative hypothesis?" The real reason is no doubt that besides the stem *to·k* "burn" Maya has the similar sounding stem *tok* (with nonlong *o*) "take away, take by force, capture, carry off," etc. The Motul has "*toc, ah, ob* (i. e., *tok*): quitar, tomar por fuerza, privar, arrebatar, robar y usurpar casas, y cosas muebles." The sign cluster *to-kak* in this case is not being used to write the compound word *to·k-k'ak'* but to write some similarly-sounding derivative or inflection of the stem *tok*, and the word probably means prey, animal taken or carried off, catch, game. Possibly the word contains *tok* and the repetitive plural suffix *-ak*, hence "(successive) catches of game." The context is enough to distinguish this word from the similarly-written word pertaining to fire.

The next sign cluster, *i-ç-mn-a*, writing the word *içamna* "Itzamna, name of the leading Maya god, the Roman-nosed god of the codices," is very important because it is the first proper name written in Maya hieroglyphs to be deciphered. Proper names and especially personal names have a peculiar convincingness in the decipherment of any script. They are ideal tools for decipherment when they can be had. When a decipherer can with the aid of his system spell out some well-known proper name which should occur in his text, he knows that he is on the right track. It will be remembered that it was the names of Ptolemy and Cleopatra in an inscription that gave Champollion his most effective clues, and similarly it was the names of Xerxes and Darius in the Behistun inscription that afforded Rawlinson his starting point for the decipherment of cuneiform. It has long been agreed that the Roman-nosed god of the codex pictures, or god D, corresponds in characters to the one traditionally known as Itzamna. His glyph is always written in this way. If we knew more of the ancient names of the gods our progress in decipherment would be materially aided. Unfortunately the god Kukulcan, who appears so frequently in the codices, evidently is not called by that name in the codices, or else if he is called by that name it is written by a unitary word sign.

The next cluster, *k-ka-haw*, representing the pronunciation *kahaw*, is to be reconstructed *ka-ahaw* "our lord," "our master," "our king." This was the characteristic epithet of Itzamna as the Maya Zeus. In the Chilam Balam of Chumayel and also that of Tizimin, this god is referred to and called *Itzamna kavil*. Here "*kavil*" equals in the Americanist phonetic system, *k'awil*, from *kahawil* (glottalization arising from loss of *-ah-*) from *ka-ahawil*, which has the same meaning as *ka-ahaw*. Thus this decipherment may be likened to Rawlinson's recognition of "king, great king, king of kings" after the name of Xerxes. The Motul defines *ahaw* as "*ahau* (*ahaw*) : rey o emperador, monarca, principe o gran señor." The preposed pronominal *ka* (traditional spelling *ca*) is the second person plural governing the following word, the translation of the relationship being possessive when that word is translated as a noun, subject when it is translated by a verb. Here of course the translation is "our." The cluster *k-ka-haw* "our lord" is an almost invariable accompaniment of the name Itzamna in the codices; rarely it is omitted, and rarely it occurs with the names of other gods. Occasionally also with names of gods we find the simple epithet *ahaw* "lord," written *a-hw*, with an *a* sign not listed in this paper but cited in slightly variant form by Landa, and with No. 6 of figure 1 for *hw*. In accordance with the general principle of Maya writing that signs may not be

used in isolation, except as day signs, the word *ahaw* is not written with sign No. 5 (*haw*) alone, except when it means the day Ahau.

Thus we arrive at our final translation: "Our lord Itzamna kindles his fire by drilling."

The importance of this decipherment and translation is quite independent of the interest or lack of interest of the subject matter. As far as concerns the information which this translation gives us about the Maya, or about its own subject matter, it is quite trivial; it is no more than we could have gathered from the pictures alone. Its importance is linguistic and philological—linguistic because it gives information about the structure of a language, as far as the writing can express it, at a certain period of past time, philological because it is precedent to the study of a literature and of culture as reflected in this literature, at a period of past time and in a historical context and perspective. From this one short sentence can be gathered a host of linguistic and philological data, only a small fraction of which has been discussed in this paper, data which can be tested and correlated, and employed heuristically in further investigations, of progressive difficulty. A very few of these further ramifications of this sentence are barely hinted at in the footnotes, which the exigencies of space have kept relatively brief. Each such footnote actually represents an extensive study. In this way the decipherment establishes itself upon a constantly growing enlacement of sentences, their translations controlled by sets of pictures, which sentences mutually give rise to a growing grammar, syntax, vocabulary, and sign list.

There are two main wrong ways of trying to read the Maya codices. One wrong way is to attempt a clean sweep of the job—to retire into seclusion and eventually emerge with a book—a book which "tells all," which reels off, interprets, explains, epitomizes, and comments on everything from page 1 of the Tro-Cortesianus to the last page of the Dresden. There have been several such books in the past hundred years. Usually such books proclaim the discovery of a key. This key is then applied at the author's sweet will, and the trick is turned as easily as a magician lifts a rabbit out of a hat. Often, moreover, such an author has exposed his slight acquaintance with the Maya language and with linguistic procedures in general. Historical writings are not to be read with keys; there is never any key but research. The amateur decipherer is prone to make a false analogy between straightforward writing and a cipher. Actually the very word "decipher" which I have employed so profusely in this essay, embodies a misconception. Why have I used it? I suppose because it is simple and vivid, it has been generally used for this sort of research, and I have succumbed to usage. But really one does not

decipher a literature, one deciphers only a cipher. A cipher is a method of writing with deliberate intent to conceal the content from those who do not possess the key. It is deciphered with a key because it has first been enciphered with a key. A straightforward writing, not intended to conceal its tenor from all but a select few, is not really deciphered; it is analyzed and translated. The methods of such analysis and translation are quite different from the methods of message decoders; they are the methods of Champollion and Young with Egyptian, of Rawlinson and Grotefend with Babylonian, of Hrozny and Sturtevant with Hittite; they are the methods of linguistics and philology.

The other wrong way of attacking the linguistic portion of the Maya codices is the Sitzenfleisch approach. It concentrates for long periods upon isolated glyphs or words, having conveniently forgotten that such things as sentences exist. Suppose that in this method one succeeds in deciphering or partly deciphering the glyph of Itzamna. Then one next spends years scrutinizing every glyph of Itzamna in the literature, noting the most minute differences, to the pen quirk, and linking it up first with every scrap of information that can be gleaned about Itzamna, then with every god in the Middle American area that can be connected with Itzamna. The mere glyph disappears from view, having served as the springboard into a sea of mythology, religion, and folklore, from which one may perhaps emerge at last with a monograph entitled "The Concept of Itzamna." This method, through concentrating entirely on word study, wanders so far from the specific incidences of the word in the texts that it finally ceases to be linguistic altogether, and becomes something else. Words are nothing without sentences. What a word is depends on what it does, i. e., on its position and function in the sentence. This is even more important than how it is written. In Maya as in English there are many homonyms, and also words which though not homonyms are written alike, as in English are *lead* (the metal) and *lead* (go in front). Hence the determination of the sounds of signs and of their glyphic combinations is only half the battle.

There is only one road to decipherment of the Maya hieroglyphs and reading of the Maya literature. It is through a growing concatenation of sentences, proceeding from the less to the more difficult, beginning with sentences whose meaning can be understood from pictures, with the linguistic interest and linguistic findings kept constantly foremost, and conclusions relative to subject matter resolutely submerged. The linguistic findings must eventually bear the scrutiny of, and become the ground of, collaboration for various linguistic scholars. One man cannot be the medium for interpreting a

literature; such a task requires the mutual contributions of many scholars who are able to proceed in general agreement as to basic principles. Linguistic principles alone carry the conviction necessary to such scientific agreement.

As the research progresses and expands and grows more sure it becomes able to read with some confidence sentences which lack pictures to control the translation. We shall thus begin to read cautiously portions of the inscriptions, and the long pictureless texts of the Peresianus codex whose meaning is now utterly mysterious. As the major linguistic difficulties are conquered the study becomes more and more philological; that is to say, subject matter, cultural data, and history play an increasing role—it becomes a matter of not only reading but of understanding as much as possible the allusions, the references, the nonlinguistic contexts, the cultural patterns which are seen by glimpses, as it were, through the bare words and grammar of the translations. This is philology. But as the base of philology we must have linguistics. Only in this way can we ever hope to understand the history and culture of the Maya.

CONTACTS BETWEEN IROQUOIS HERBALISM AND COLONIAL MEDICINE[1]

By WILLIAM N. FENTON

Bureau of American Ethnology

[With 5 plates]

INTRODUCTION: THE COUNTRY AND THE PEOPLE

A traveler of the seventeenth century leaving the cedar-lined banks of the St. Lawrence River to ascend the Great Lakes would have encountered Indians living inland from both shores who continued to speak related dialects of the Iroquoian language as he passed Niagara and went on across southern Ontario toward the Detroit River. South of Lake Ontario lay the country of a great confederacy known to the French as the Iroquois and to the English as the Five Nations: the Mohawk, Oneida, Onondaga, Cayuga, and Seneca tribes who populated a dozen ragged villages across New York; but the cognate Neutral of Ontario and the Huron near Georgian Bay were never part of the great League, which the Tuscarora of North Carolina joined as the sixth nation in 1722.[2] In common these tribes shared generalized cultural as well as linguistic similarities that set them in sharp contrast with Algonquian hunters living north of them. But for the individual the local band was society and he knew best his own village and the surrounding woods and fields where he hunted and collected plant foods. Particularly was this true of women who remained at home to till the fields, seldom traveling on tribal business or on the warpath. Villagers discovered and sampled the flora of their local habitats during a continual search for food. Many plants were known or discovered to have medicinal properties, while a few tragic events served to remind the cautious experimenter that certain plants are poisonous so that he must be careful about

[1] This article publishes the first part of a longer study, "Herbs and Herbalists among the Iroquois Indians," which is the further extension of a preliminary report entitled "An Herbarium from the Allegany Senecas," published *in* The Historic Annals of Southwestern New York, pp. 787–796, edited by Doty, Congdon, and Thornton. Lewis Historical Publ. Co., New York, 1940.

[2] For the territories of the Iroquoian tribes see the maps and the writer's paper *in* Essays in Historical Anthropology of North America, Smithsonian Misc. Coll., vol. 100, 1940.

biting indiscriminately into all roots. Thus fear and cultural conservatism and, perhaps, lack of interest, save in dire necessity, prevented all but a few individuals from acquiring systematic knowledge of the flora. Probably very few old men and women throughout Iroquoia, who through specialization were regarded as authorities, could distinguish 300 species in a region that has yielded modern botanists five times that number. An occasional herbalist might recognize a third of the local flora. Nevertheless, the Iroquois were aware of changes in topography and ecology that a traveler would note as he passed from the coniferous forests north of the Mohawk country, through predominantly beech-birch-maple forest in Oneida and Onondaga territory, across elm bottoms and hemlock swamps to the mucky land of the Cayuga; thence having passed the Seneca towns, he would cross the Genesee, beyond which "oak openings" or prairies in western New York were skirted by great stands of basswood and white pine, and where such typically southern species as sassafras, tulip, and cucumber trees blended into the oak-hickory-chestnut forest of the Allegheny uplands (pl. 1, fig. 2). If the beech was the most numerous upland tree of the Iroquois country, the maple was more important in economy and religion: to this day it is remembered with an annual festival of thanksgiving. Stately white pines towered on the river terraces and invaded abandoned village sites, but until after the introduction of the steel ax the pine was not as important to the Iroquois for house building (pl. 2, fig.1) as the bottomland American elm, which must have been an important species in the primary forests of their region because they extensively used its bark for houses, vessels, and boats, and it was the prominent tree symbol of mythology and art.[3]

Since the culture of every society exists over and against an environment, it becomes important to observe how a people adjust to it, to what degree they exploit it, how its offerings affect the contents of their behavior, and how they react to new discoveries. Studies of how peoples of primitive culture use plants (ethnobotany) in relation to the possible uses of plants to man (economic botany) yield information for elaborating this type of problem. Because plant lore and knoweldge of medicinal uses tend to survive among peoples like the Iroquis the ethnologist can undertake such studies on their reservations that form island communities in the surrounding sea of whites. Here one may observe the clash of cultures in a patient who calls in the Government physician and later summons his wife's mother, a noted herbalist. Reservations provide nexus of

[3] Zenkert, Charles A., The flora of the Niagara frontier region. Bull. Buffalo Soc. Nat. Sci., vol. 16, 1934; Gordon, Robert B., The primeval forest types of southwestern New York. Bull. New York State Mus., No. 321, 1940.

kin, locality, and dialect, permitting some Iroquis to retreat from the modern world of frustration into a native religion that furnishes delusions of past political granduer and quasi health insurance in Indian herbalism. Thus the Indian herbalist, bolstered by a native religion and the belief of many ignorant whites in his universal knowledge, is encouraged to preserve the ethnobotanical knowledge of his grandparents whose ancestors learned plant uses for the flora of the region his people continue to inhabit (pl. 2, fig. 2). To what he can retain of this fund of family knowledge, the modern Iroquois adds the plants that he collects for drug traders and other popular practices that the whites have proved to him to be effective. Moreover, discounting plant species and usages of obvious European introduction and checking one informant against another, one can readily assemble a respectable list of plants and their Indian names which have currency in the Iroquois community and are probably ancient. Similarly, if we compare them tribe by tribe and reservation by reservation, those names and usages that are now widely separated in time and space and yet are demonstrably equivalent date back to the time when the Iroquois tribes were inhabiting neighboring territories, or to a still earlier time.

Since so much of Iroquois culture has the mark of a southern origin, it would seem that, as they moved into the area which they inhabited during historic times, not only was it important for them to discover new edible fruits, but a host of plants awaited technological and medicinal experiment. Possibly Algonquian neighbors had devised some uses which they showed them, but to other plants the Iroquois have applied concepts that relate to analogous domestic or known southern species. However, those plants which are named for maize may reflect a process of reinterpretation following long years of maize cultivation in the north. In comparing present Iroquois and Algonquian plant names we find some names that have similar meanings and yet we cannot be sure in which direction such ideas traveled.

INDIAN AND COLONIAL MEDICINE

10th: I give a beverage made from an excellent white root, with which diseases of all kinds are cured in my country.—*Speech of a Mohawk envoy at Quebec*, 1659.[4]

Contact between Indian herbalism and western medicine was a natural result of colonization. When they met in the early sixteenth century European medicine was still carrying a heavy burden of medieval practices so that the few first physicians in the colonies were but several centuries advanced from the Indian shaman who selected

[4] Jesuit Relations, vol. 45, p. 83.

his herbs thinking of the effect that their appearance might contribute to the disease, and guaranteed their efficiency with incantations and feats of magic. Moreover, the average settler had brought from the old world a knowledge of herbs that in kind was not unlike that of the Indian, but as newcomers they were unfamiliar with New World plants; and although the level of their own popular medicine did not set them above adopting Indian remedies, the Indian herbalist whose knowledge was power was not always a ready teacher. Two centuries of missionary, military, and scientific travel were to enlarge medical botany until many new world plants in use by the Indians were to become part of our pharmacopoeia. To this fund of knowledge the Iroquois contributed a share.

The Canada band of Laurentian Iroquois, at that time living in the environs of Quebec, made a sensational beginning as teachers when in 1536, after 25 of his able seamen had died of scurvy, they showed Cartier how they obtained relief from a simple decoction of the bark and needles of hemlock (*Tsuga canadensis* (L.) Carr.), or white pine (*Pinus strobus* L.).

> One day our captain, seeing the disease so general and his men so stricken down by it, * * * caught sight of a band of Indians approaching from Stadadona [Quebec], and among them was Dom Agaya whom he had seen 10 or 12 days previous to this, extremely ill with the very disease his own men were suffering from; for one of his legs above the knee had swollen to the size of a 2-year-old baby, and the sinews had become contracted. His teeth had gone bad and decayed, and the gums had rotted and become tainted. The captain, seeing Dom Agaya well * * * was delighted, hoping to learn what had healed him, in order to cure his own men. And when the Indians had come near the fort, the captain inquired of him, what had cured him of his sickness. Dom Agaya replied that he had been healed by the juice of the leaves of a tree and the dregs of these, and that this was the only way to cure sickness. Upon this the captain asked him if there was not some of it thereabouts, and to show it to him that he might heal his servant who [in his opinion] had caught the disease when staying in Chief Donnacona's wigwam at Canada, being unwilling that he should know how many sailors were ill. Thereupon Dom Agaya sent two squaws with our captain to gather some of it; and they brought back 9 or 10 branches. They showed us how to grind the bark and the leaves and to boil the whole in water. Of this one should drink every 2 days, and place the dregs on the legs where they were swollen and affected. According to them this tree cured every kind of disease. They call it in their language Annedda.[8]

Until recent times hemlock tea has been a favorite winter beverage with the Iroquoian tribes whose names for hemlock, or evergreen, are clearly cognate with the term given Cartier. Curiously enough he says that this decoction brought miraculous relief in longstanding cases of venereal disease among the sailors, and modern Iroquois

[8] Biggar, H. P., ed., The voyages of Jacques Cartier, Publ. Public Arch. Canada, No. 11, pp. 212–213, *et supra*, Ottawa, 1924.

herbalists employ the hemlock as an ingredient in formulae for boils and venereal disease. This is an interesting fact historically, whether or not the plant is a specific for the disease. Seventeenth-century travelers were unable to rediscover the famous tree, because the Laurentians had abandoned their Quebec towns in the intervening decades and the succeeding Algonquians did not employ it as an anti-scorbutic.

The seventeenth-century Huron and Iroquois distinguished among them shamans who cast and removed spells, clairvoyants who diagnosed disease or foretold weather and future events or recovered lost objects, and herbalists or apothecaries who administered remedies. Frequently, several roles were combined in a single individual. Here principally the herbalist interests us, although he seldom administered his simples without a modicum of ritual to impress the expectant patient.[6]

Against such competition the Jesuit and Franciscan missionaries to New France labored with all their wits and the skills of European civilization. Such medicines as they had brought or they were able to import from their brothers in Europe and the lancet were potent weapons in the conversion of the Indians who took readily to being bled. During the summer and fall of 1636 and throughout the winter of 1637 when a great contagious epidemic leveled the villagers of Huronia, Father Joseph LeMercier wrote:

> Everything was given by count, two or three prunes, or five or six raisins to one patient; * * *
>
> Our medicines produced effects which dazzled the whole country, and yet I leave you to imagine what sort of medicines they were! A little bag of senna served over 50 persons; and they asked us for it on every side; * * *[7]

Undismayed, the Huron shamans combated this success with dreams of visits to an inhospitable French heaven, with tales that the French are sorcerers, and that the faithful before the epidemic had believed only to get tobacco; and the missionaries had no sooner gotten the Indians to acquiesce to forsaking their dream feasts to avert the wrath of God in the pestilence than an unusually adept shaman ordered the False-faces to purge the cabins of disease. LeMercier continues:

> Towards evening [8th February, 1637; at *Ossosané*, great town of the Bear band of Huron], the Captain *Andahiach* went through the cabins to publish a new order of the sorcerer *Tsondacouanné*. This personage was at Onnentisati, and was not to return until the next day. He was carrying on his preparations, that is to say, certain sweatings and feasts, in order to invoke the assistance of

[6] For a compendium of the principal sources on shamans and medical practice among the Huron at this period, consult Kinietz, W. Vernon, The Indians of the Western Great Lakes, 1650–1760, Occas. Contrib. Mus. Anthrop., Univ. Michigan, No. 10, pp. 131–160, 1940.

[7] Le Jeune's Relation, 1637, *in* The Jesuit Relations and Allied Documents, Reuben Gold Thwaites, ed., vol. 13, pp. 113, 115, Cleveland, 1898.

the demons, and to render his remedies more efficacious. This prescription consisted in taking the bark of the ash, the spruce, the hemlock, and the wild cherry, boiling them together well in a great kettle, and washing the whole body therewith. He added that his remedies were not for women in their courses, and that care should be taken not to go out of their cabins barefooted, in the evening.[8]

Similar decoctions were in use among the Mohawk of Caughnawaga in cases of colds, coughs, and rheumatism as recently as 1912, and the tabu is characteristic of later Iroquois belief.

In the face of these circumstances the French missionaries were naturally slow to adopt new remedies when the supply that they had brought with them ended, while in the tiny center of French culture at Quebec European medicines were used almost exclusively. After 1640 we read long lists of medical necessities required by the hospital nuns of Quebec who were treating Indian patients for smallpox that had come to them from Europe. Into the Ursuline hospital willing Indian patients brought some folkways of the forest. The Mother Superior speaks of them in Le Jeune's Relation of 1640:

The remedies that we brought from Europe are very good for the Savages, who have no difficulty in taking our medicines, nor in having themselves bled. The love of the mothers toward their children is very great, for they take in their own mouths the medicine intended for their children, and then pass it into the mouths of their little ones.[9]

Two years later they dispensed over 450 medicines and their supply was exhausted. The long list of necessaries of which they suffered a great lack in the year 1665, for the relief of the patients then there in large numbers, pleads for senna, rhubarb, jalap, and theriac, among others; and for succeeding years there are similar, shorter lists.[10]

However soon these deficiencies were corrected by cultivating herbs in Quebec, as early as 1641 Charles Garnier in a letter thanking his brother for a memorandum of the easiest remedies, which were nevertheless difficult because the ingredients were scarce in Canada, begged for some medicinal seeds useful as purgatives and for information concerning their growth which he contemplated at the mission of Ste. Marie in the Huron country.[11]

A generation later, Lamberville, among the Onondaga near Syracuse, bemoans the lack of a quantity of medicines as an aid to converting the sick.

It would be a bait wherewith to secure nearly all The dying. There are some who, when they find that They are given no medicine, turn Their backs

[8] Idem., p. 261.

[9] Jesuit Relations, vol. 19, p. 21.

[10] Ibid., vol. 22, p. 173; vol. 49, pp. 205–207; vol. 50, p. 161; vol. 51, p. 113; vol. 52, pp. 107–109.

[11] Ibid., vol. 20, p. 101.

to me, and say that I have no pity on them, and after that they cannot be approached.[13]

And the following year some ointment that had been sent him proved a sovereign remedy for ulcers; but just at the point where he had gained prestige with his first cure, the supply gave out and his case was lost.[13] On the other hand, to offset the successes which the Jesuits claimed we have Baron Lahontan's statement that the Indians in his day were opposed to making use of French medicines and surgeons.[14]

The picture that we have developed of Indian medicines during the period of its failure to cope with introduced European diseases leads us to inquire how successfully native herbalists treated indigenous ailments. Early travelers remark that certain diseases then common among Europeans were unobserved among the northeastern American tribes. Among these, gout, gravel, and dropsy were mentioned by Lahontan.[15] On the other hand, ailments growing out of their way of life were more frequent: prolonged fasts followed by feasts and periods of famine induced digestive disturbances; rheumatism , neuralgia, pleurisy, and pneumonia were not uncommon among the Iroquois; and long years of group living in smoke-filled longhouses brought on conjunctivitis with advancing years; while wounds, dislocations, and fractures were risks in a life on the warpath and the hunt. Possibly asthma and dropsy accompanied advanced age;[16] and the great number of prescriptions for deficiencies of the blood and uterine disorders suggest anemia and complications following childbirth. Zeisberger's description of hardships and disease among the Delaware and Iroquois in the middle eighteenth century is probably typical of earlier times.

Indians are not less, rather more, subject to disease than Europeans, their rough manner of life and the hardships of travel being contributing causes. On journeys they mind neither water nor snow nor ice, even though creeks and rivers be ever so full of running ice they go through and nothing holds them up. On the chase they not only steal through the woods to get, unnoticed, near the game, but also pursue it * * * until they get within range, thus * * * they may have chased from morn til eve * * * sometimes 8 or 10 miles away from their hunting lodge, no food having been tasted the entire day. So long as they are young and strong, they suffer no ill effects, but with advancing years * * * Rheumatism is common among them, often leading to lameness, deafness or blindness. The women who carry everything by means of a carrying girth fixed to the forehead, whence the whole burden—and a hundred weight is not considered heavy—is suspended down the back, suffer

[13] Relation of 1672–73, Jesuit Relations, vol. 57, p. 173.
[13] Ibid., vol. 58, pp. 211–213.
[14] Lahontan, Baron de, New voyages to North America, vol. 2, p. 50, London, 1703.
[15] Idem, pp. 45–46.
[16] Stone, Eric (M. D.), Medicine among the American Indians, pp. 23–26, Clio Medica, New York, 1932; Corlett, Wm. Thos. (M. D.), The medicine-man of the American Indian, pp. 55–56, Chas. C. Thomas, Springfield, Ill., and Baltimore, 1935.

in back and neck as they grow older. The men carry everything fixed to a carrying girth fixed across the chest. A deer weighing from a hundred to a hundred and thirty pounds they will carry the entire way home without allowing themselves to rest.

* * * * * * *

They are subject to festering sores. Cured in one place they break out in another. Chills and fever, dysentery, hemorrhage, and bloody flux in women are very common among them. Venereal diseases having during the last years spread more and more, * * *[17]

The latter and possibly tuberculosis were the worst of the imported infectious diseases which included measles, scarlet fever, diphtheria, chickenpox, smallpox, typhus, typhoid, malaria, and yellow fever.[18] Were it not for these introduced contagions, says the Jesuit ethnologist François Lafitau, who visited the Caughnawaga Mohawk band and the Abenaki of St. Francis during the second decade of the eighteenth century, and scrofulous maladies caused by hardness of drinking water melted from snow and a kind of phthisis (consumption) contracted by exposing chest and abdomen to winter blasts, for which they had developed no remedy, and which carried a majority to the grave ere the prime of life, their otherwise rigorous constitutions stood them to an extreme old age in which they had either to be knocked on the head or suffered to go out like a light by a mere default of nature.[19]

The early writers are unanimous in agreeing that Indians, including the Iroquois, possessed some natural remedies capable of checking endemic diseases, but assert that they excelled even European surgeons at healing wounds, setting fractures, and replacing dislocations. The Iroquoian-speaking Wenro tribe were reported in the year 1639 when they migrated from western New York to Huronia on Georgian Bay "* * * to excel in drawing an arrow from the body and curing the wound; but the prescription * * *" was thought to have no efficacy unless a pregnant woman were present, whose condition in later times was generally considered bad luck in medicine.[20] Incidents from Indian wars furnish abundant evidence of this skill. An Iroquois prisoner among Hurons has his thumb and forefinger done up in "some leaves bound with bark;"[21] Father Poncet, captured, tortured, and finally delivered as a relative into an adopting Mohawk family, had an amputated finger cauterized with an ember and wrapped in a leaf of Indian corn. Subsequently it was poulticed

[17] Zeisberger, David, A history of the Indians. Ohio Arch. and Hist. Soc. Publ., vol. 19, pp. 23–24, 1910.

[18] Heagerty, J. J., Four centuries of medical history in Canada, 2 vols., vol. 1, p. 270, Toronto, 1928.

[19] Lafitau, J. F., Moeurs des sauvages Amériquains, 2 vols., vol. 2, pp. 359–361, Paris, 1724.

[20] Lalement *in* Le Jeune's Relation, 1639, Jesuit Relations, vol. 17, p. 213.

[21] LeMercier (1636), Relation of 1637, Jesuit Relations, vol. 13, p. 41.

for a fortnight with a decoction of some unknown roots or barks, "which they wrapped in a linen rag that was greasier than a kitchen-cloth."[22] Dutch writers of the period also attest that there must be valuable simples in the colony of New Netherlands because the Indians know how to cure very dangerous wounds, sores, and bruises in a most wonderful manner with herbs and roots and leaves which grow in their country and are known to them.[23] The Relation of 1663–64 conveys some notion of the skill of Mohawk surgeons in the adventure of three soldiers of the garrison of Three Rivers, Quebec, who were ambushed by Mohawk warriors on the Richelieu Islands. In the attack a ball passed through the body of one and lodged at the side opposite its entry. We read:

> The Iroquois—who take pride in leading home prisoners alive and full of strength, to endure the strain of torture * * *—turned Physicians * * * and, with cruel compassion, dressed his wound and bled him * * *. They probed the wound full through his body, and finding the place where the ball had stopped, made an incision there and removed it, with admirable skill. After this successful operation, it is incredible what pains and care they took of this poor patient. Some would cleanse the wound and infuse into it the juice of roots, either boiled or chewed, which is a sovereign remedy with them; others would bandage it * * *.

That he survived to run the gauntlet before a Mohawk town and subsequently escape near Oneida is almost as remarkable as his blundering into the cabin of a captive woman who had been reared by the Ursulines of Quebec.

> For she set about * * * preparing a fire for them, giving them something to eat, and wiping the matter from their sores, without showing any disgust at the stench which arose from those ill-dressed ulcers. She even went to fetch some medicinal roots, and made of them a dressing, which she applied to all the places * * * where the gangrene seemed most dangerous, and cleansed the others— * * * omitting nothing * * * that a wise and kind surgeon could do.[24]

Indians apparently were not as subject to gangrenous infections as the French. Lahontan (vol. 2, p. 50) attributed this to the Indians' hail constitutions, not to the quality of the herbs employed, because notwithstanding the use of the same remedies gangrene invaded the wounds of the French. Indians attributed this to eating salt. The present-day Iroquois abstain from eating salted foods while under treatment of the sacred Little Water Medicine, a mixture of powdered vulnerary herbs and animal hearts composing their sacred war bundles. That the Mohawk of Caughnawaga knew this formula at

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[22] Relation of 1652–53, Jesuit Relations, vol. 40, pp. 139, 143.

[23] Van der Donck, Adriaen, Description of the New Netherlands. Coll. New York Hist. Soc., 2d ser., vol. 1, p. 207, New York, 1841; The representation of New Netherland, 1650, *in* Narratives of New Netherland, J. F. Jameson, ed., pp. 299, 301, New York, 1909.

[24] Jesuit Relations, vol. 49, pp. 121, 129.

the beginning of the eighteenth century seems probable from Lafitau's essay on medical practices. He says that the healing of wounds was the masterpiece of their operations, that they were on the verge of something so remarkable as to be almost unbelievable. One Mohawk warrior who went against the Fox Nation had his shoulder fractured by a gunshot during the attack on a Kickapoo village; yet he survived hunger and the discomforts of a journey of 700 leagues (2,100 miles) to be treated by a tribal surgeon. To effect these marvelous cures, he says,[25] they concocted a treacle water[26] composed of several classes of ingredients. The first group included vulnerary herbs, graduated according to their properties. Next were vulnerary trees from the trunk or root of which splinters were taken. The third was derived from the bodies of divers animals, especially the heart, which, dried and powdered, was made into a mastic. His description of the solution of the first of these sounds very much like the modern "Small dose," or Little Water Medicine, of which very little is used and the fluid appears almost colorless. He says its effect is to push out not only vicious humors that have the habit of forming in the wound, but also the splinters of broken bones and arrowheads. The patient is given some to drink and is kept away from all nourishment while in danger, although in modern cases light unsalted breads and white meats are given. Meanwhile the doctor drinks some of the solution himself to the end that his saliva is saturated with it, before sucking the injury or spraying it with his mouth, the latter being the modern practice. Lafitau attaches great importance to the practice of covering the wound so as to exclude contact with everything save a possible binding of boiled herbs, which they think prevents infection. He continues that when the wounds are dressed and the above operation repeated the wounds always appear clean and fresh and free of clots; and provided that the sick man is careful he is soon healed. Whereas Lahontan has argued that eating no salt facilitated these cures, Lafitau thought that the healing followed principally from the efficacy of their vulneraries and particularly from the precautions taken to prevent the wound from becoming exposed to the air. Whatever the validity of his arguments a chemical analysis of samples of the modern plant and animal powders would be interesting.

Indian surgeons were apparently as successful with fractures and dislocations. However, Lafitau's assertion that they did not perform less well with ruptures and hernias and that broken bones mended in 8 days' times is questionable. The important fact historically is that

[25] Lafitau, J. F., op. cit., vol. 2, pp. 365–366 ff.

[26] *Theriaca,* Lat., was an antidote, or medicine to counteract the effects of poison, originally against the bites of wild beasts; and such preparations were frequently carried by the Jesuits in New France.

these early medicine men undertook the same types of cures that are also attributed to their descendants, the present holders of the Little Water Medicine bundles. As specialists the latter profess some feats that were formerly performed quite commonly by hunters, among whom dislocations were more frequent than fractures.

If an Indian has disclocated his foot or knee, when hunting alone, he creeps to the next tree, and tying one end of his strap to it, fastens the other to the dislocated limb, and lying on his back, continues to pull it till it is reduced.[26a]

Sweat lodges were formerly a common feature of Indian settlements throughout the eastern woodlands. They were usually situated on the edge of the village near a stream where they served not only as a regular place of bathing, but provided also a retreat for the shaman and the men of the village who gathered there for ceremonies and recreation. The songs which the Medicine Company continues to sing among the modern Iroquois refer to prominent features of sweating, for example the rise and condensation of steam, juggling with hot rocks, and tossing songs across a fire; but the sweat lodge has not survived as a reservation institution. Nevertheless, for a time it came into general use among the colonists of the maritime provinces of Canada.[27] Lafitau's description is probably typical of those in use among the Iroquois:

The sweat bath is their most universal remedy, and of it they make a great deal of use. It is equally for the sick and the healthy, who thus are purged of abundant humors, which can have changed their health, or might in the end have caused infirmities.

The sweat bath is a little round cabin 6 or 7 feet high with room for seven or eight persons. This cabin is covered with mats and furs to protect it from the outside air. In the middle of it they put, on the ground, a certain number of cobbles, which they have left for a long time in the fire until they have been thoroughly heated, and above these they suspend a kettle full of cool water. Those who are to sweat themselves enter this cabin nude, * * * and having taken their place, granted that they are not to transact secret business, * * * they begin to stir extraordinarily, and to chant, each his song. [Singing individual songs of power is a feature of the Medicine Society meetings.] And as the tunes and words are often entirely different, it is the most disagreeable and discordant music to which one could possibly listen.

From time to time, when the stones begin to lose their action, they revive them by dousing them with a little of this cold water which is in the kettle. This water no sooner touches the stones than a vapor arises which fills the cabin and greatly increases the heat in it. They throw in each others' faces this cool water in order to prevent themselves from fainting away. In an instant their bodies stream from all parts; and when their pores are well open and the sweat is most plentiful, they go out all singing and run to plunge into the river, where they swim and flounder with much vehemence. Some, the ill ones

[26a] Loskiel, George Henry, History of the mission of the United Brethren among the Indians of North America, LaTrobe trans., p. 112, London, 1794.

[27] Bailey, Alfred Goldsworthy, The conflict of European and eastern Algonkian cultures, 1504–1700 Publ. New Brunswick Mus., Monogr. Ser. No. 2, p. 121, St. John, New Brunswick, 1937.

in particular, content themselves with being sprinkled with cool water. It seems as if the contrast of an extreme heat with the cold of the water ought to seize them and cause their death * * *; but they have the experience that it does them good which is worth more than all the arguments that one could make.[28]

Plant remedies passed between Indians and the colonists of New France, New England, New Netherlands, and New Sweden to an extent that is difficult to estimate, and frequently the direction of borrowing is uncertain. Seventeenth-century explorers were on the lookout for plants which had been reported as sovereign remedies against maladies that were current in Europe, and the rapid spread from country to country of certain species like tobacco and sassafras, the history of which is known, attests their wide acceptance into European medical practice. Inadequately described at first, some were to remain unknown botanically until the middle of the eighteenth century, when collecting was stimulated in America to furnish seeds for exotic gardens that were becoming fashionable in England, and systematic botany was coming into being under Linné in Sweden. The latter's student, Peter Kalm, and John Bartram, Philadelphia botanist, were often hard put to decide which plants a century after contact were native and whether Indians or colonists first used them medicinally.

The first plants reported by whites and adapted to their use were those which Indians used most effectively. In New France, following the mystery of Cartier's Annedda, Champlain (1615) and Sagard (1623) reported several medicinal plants which were long known only by their Huron names that sometimes enable us to identify them. There are two poisonous plants, for which there is a long subsequent literature relating to their use in Huron and Iroquois suicides:[29] mayapple (*Podophyllum peltatum* L.), which has an edible fruit but a poisonous root, was clearly described by Champlain; and Sagard discovered Ondachiera, the deadly waterhemlock (*Cicuta maculata* L.) (pl. 3, fig. 1). When individuals accidentally ate of these, the Indians employed powerful emetics as antidotes; but they also understood that mayapple furnished a reasonably safe cathartic if they first baked the poisonous podophyllin from the roots; and of waterhemlock and its relatives their physicians used the roots in poultices for reducing sprains and inflammations. The plant known as Oscar, "which does wonders in healing all kinds of wounds, ulcers, and other sores,"[30] might possibly be bloodroot, basswood, or sassafras; but phonetically, it more closely resembles onaahra'ge'ha

[28] Lafitau, J. F., op. cit., vol. 2, pp. 371–372.

[29] Fenton, William N., Iroquois suicide * * * Bur. Amer. Ethnol. Bull. 128, Anthrop. Pap., No. 14, pp. 80–137, 1941.

[30] Sagard, Father Gabriel, The long journey to the country of the Hurons, p. 195, George M. Wrong, ed., Champlain Soc., Toronto, 1939.

(M.), "stump dweller," the common elder (*Sambucus canadensis* L.) or 'oskaá'a (S.), the hellebore (*Veratrum viride* Ait.),[31] the use of which in wounds has been attributed to the Penobscot and Micmac of Maine and New Brunswick.[32]

The ignorance of the French colonists provided the Indians with some amusing incidents when they did not have tragic consequences. A French boy in Sagard's party set all the Hurons laughing when, having teased some Huron children to share with him some roots called Ooxrat which they were carrying home, he burned his mouth badly on biting into them. The appreciative savages had long since learned to avoid the stinging pain by first cooking the roots in hot ashes, and they used them * * * "to purge the phlegm and moisture in the head of old people and to clear the complexion; * * *" Although Ooxrat has the smarting properties of hellebore 'oskaá'a (S.), the dried root of which is still popular among the Iroquois as a snuff for catarrh, the fruit and root of Indian turnip or Jack-in-the-pulpit (*Arisaema triphyllum* (L.) Schott) produces the burning sensation mentioned, and its Cayuga name, owa'hṵshra', "cradleboard," resembles Huron Ooxrat.

A reporter on New Netherlands, in 1650 without professed skill in medical botany found with little effort over 30 plants which he thought might convey a notion of the valuable plants that were known to the Indians. Of these, we recognize the following as herbs in use among the Indians of later times: polypody, mullein [introduced from Europe], priest's shoe, sweet flag, sassafras, crowfoot, plantain [introduced], mallow, laurel, violet, blue flag, wild indigo, Solomon's seal, dragon's blood, milfoil, fern[?], agrimony, wild leek, snake root, and prickly pear.[33]

The histories of three American plants that were used medicinally by the Iroquois—sassafras, maidenhair fern, and ginseng—are sufficiently documented to serve as examples of how the Iroquois contributed to the introduction of medicines into Europe. Sassafras, known to the Seneca as "rough bark" (ono'hsta'shɛ'), and employed by all the Iroquois as a tonic, created at one time in Europe a stir like that which attended the discovery of the sulfanilamide series or vitamins in our own time. Brought to Spain after the middle of the sixteenth century from Florida, where French Huguenot refugees

[31] *Phonetic note.*—The orthography employed in this paper for writing Iroquois words has the same phonetic values as explained in "Iroquois suicide * * *" cited above, with a single innovation of denoting long vowels by doubling them instead of employing a raised period after the vowel to indicate length.

Abbreviations in parentheses following Indian words refer to dialects of Iroquois as follows: (M.), Mohawk; (Oe.), Oneida; (Oa.), Onondaga; (C.), Cayuga; (S.), Seneca; (T.), Tuscarora; and (H.), Huron.

[32] Stone, Eric, op. cit., p. 80.

[33] The representation of New Netherland, 1650, p. 298.

had learned its use in fevers from the Indians, it was described by Nicolaeus Monardes of Sevilla (1574) and it was soon imported into Europe in large quantities. Spreading from Spain and France, its use became well known in Frankfort-on-Main in 1582 and in Hamburg a few years later. Such was the demand for the new drug that sailing expeditions were despatched to America to bring back the root. An English merchant, Martin Pring, visited the American coast in the summer of 1603, and following it to the south in search of sassafras, returned in August, his two vessels laden. Until 1622 Virginia colonists were drawing the roots in winter and exporting them in quantities equal with tobacco.[34] That so valuable a drug was growing in the Iroquois country naturally pleased the founders of the short-lived French colony at Onondaga Lake. Its presence there furnished Father Dablon a pleasant topic to offset some hardships in writing "Of the nature and peculiarities of the Iroquois country."

> But the most common and most wonderful plant in those countries is that which we call the universal plant, because its leaves, when powdered, heal in a short time wounds of all kinds; these leaves which are as broad as one's hand, have the shape of a lily as depicted in heraldry; and its roots have the smell of the laurel. The most vivid scarlet, the brightest green, the most natural yellow and orange of Europe pale before the various colors that our savages [the Onondaga] procure from its roots.[35]

Since it had been long known among them as a blood purifier, it is not strange that the Iroquois employed it to heal venereal diseases; Lafitau implies this use was ancient on the supposition that these diseases were carried from America to Europe.[36] Regardless of the origin of these diseases, by the middle of the eighteenth century, when the work of Kalm and others made sassafras known botanically, its use in their cure was so well known in Europe that English gentlemen had abandoned drinking tea of sassafras flowers lest in using it they be suspected of infection. Kalm found the Swedes of New Jersey putting sassafras peels in beer, recommending it as an insecticide against moths and bedbugs to the extent of turning their bedposts out of the wood; and the women of Philadelphia had learned, perhaps from the Delaware, to make a fast orange dye for worsteds. Medicinally, an old Swedish woman had employed a decoction in cases of dropsy; and near Albany, Kalm learned that the natives [Mohawks?] considered the sassafras valuable in treating diseased eyes.

> They take the young slips, cut them into halves, scrape out the pith or the medulla, put it into water, and after it has been there for some time, wash the

[34] Lloyd, John U., Laurus Sassafras, *in* Pharmaceutical Rev., December 1898, pp. 450–459.
[35] Relation of 1656–57, Paul Le Jeune, ed.; Jesuit Relations, vol. 43, p. 259.
[36] Lafitau, J. F., op. cit., vol. 2, p. 368.

eyes with the same water * * * natives from Canada formerly * * * cut the stems in two, took out the pith and preserved it and took it home with them to use as described above.[37]

Living at the northern extremity of its range Iroquois uses of sassafras were typical of tribes farther south. Seneca warriors carried the powdered leaves, women employed it as a tonic after childbirth, it was used in cases of rheumatism, and as a diuretic; and drinking sassafras tea as a spring tonic has so long ago become a part of life on the American frontier that the Iroquois herbalists have regularly peddled the root bark on the doorsteps of their white neighbors. In the modern city of Buffalo the Indians still maintain the right to sell sassafras and wildflowers in season from certain street corners, and choice stations are annually preempted by old Seneca families of Tonawanda and Cattaraugus reservations. Some years ago when the matrons of the Bear clan at Tonawanda were considering the nomination of a recently deceased Sachem, someone remarked, "All he knows is how to sell sassafras!"

Maidenhair fern (*Adiantum pedatum* L.) attracted much attention in the colonies. For its most conspicuous feature, a black stalk, it was generally known among the Iroquois as "black shins" (degányendaaǰi's(S.); degodisinahumǰi's(M.)). Mohawk and Seneca midwives recommend it as a haemostatic in women's disorders and for labor pains. Its earlier uses which made it a popular export item from New France do not appear in Waugh's or my own notes.

Several people in Albany and Canada assured * * * [Kalm (1749)] * * * that its leaves were very much used instead of tea, in consumption, cough, and all kinds of pectoral diseases. This they have learnt from the Indians who have made use of the plant for these purposes since ancient times. This American maiden hair is reckoned preferable in surgery to that which we have in Europe and therefore they send a great quantity of it to France every year.[38]

The export trade in this drug was flourishing as early as 1687 when Lahontan observed * * * "that the Inhabitants of *Quebec* prepare great quantities of its Syrup which they send to *Paris*, *Nants*, *Rouan*, and several other Cities in *France*."[39] In Kalm's day the price varied according to the grade of the plant, the care taken in preparing it, and the quantity available at Quebec. The Indians went into the bush about the first of August and traveled far above Montreal in quest of it.

Of greater importance financially and more pertinent to a discussion of Iroquois herbalism than either sassafras or maidenhair fern

[37] Peter Kalm's travels in North America, pp. 180, 179, 78, 606, Adolph B. Benson, ed., New York, 1937.

[38] Idem, p. 438.

[39] Lahontan, Baron, de, op. cit., vol. 1, p. 253.

was the discovery of an American species of ginseng in the forests bordering the St. Lawrence near Montreal. Ginseng had long been a common drug among Iroquois herbalists, who set no especial value on it until an artificial demand for it created by the China trade raised the price out of all proportion to its medicinal properties. The burgeoning traffic in ginseng was to bring illusions of wealth to the French colonists and stimulate a search by both white and Indian ginseng hunters that within a century would nearly eradicate the wild species in northeastern America. In 1709 Father Jartoux, a French Jesuit missionary to China, had undertaken a mapping expedition into inner Tartary for the Chinese monarch; there he met 2,000 natives occupied in hunting a plant they called Gin-seng, which commanded a high price in oriental markets. Jartoux's paper entitled "A Description of a Tartarian Plant called Gin-seng," which appeared subsequently in the Philosophical Transactions of the Royal Society of London, came to the notice of a brother Jesuit, Joseph François Lafitau (1681–1746) during a visit in 1715 to Quebec on business for his mission (pl. 1, fig. 1). Lafitau had come out to America in 1711 to work among the Caughnawaga band of Mohawk living at Sault St. Louis above Montreal where he remained during 6 years before returning to France. Scholar, botanist, and ethnologist, he vainly searched the Relations for references to the plant, but he did not abandon hope of finding it growing in Canada, the ecology of which impressed him as being markedly similar to that of Tartary; and in thinking that the native Indians were related to Tartars, he was among the earliest writers to develop the theory of an Asiatic origin for the American Indian. He held that because the French of Canada had an inferior regard for Indian medicine, the Jesuits had not made such remarkable discoveries as their brothers in South America. Sparing what time he could from missionary labors and exercising care not to antagonize his brothers by seeming to confirm native beliefs, or to arouse the suspicions of the Indians by manifesting too much interest in their culture, he made field trips and questioned Mohawk herbalists who appeared to know many of the excellent plants that filled America. To one who displayed such respect for their ability, they were not opposed to divulging some private knowledge which was hereditary in their families, and they encouraged him to continue his search because they hoped he would find the plant which he described to them. Although such interviews were not advancing the ginseng quest, they provided a body of data on native customs and beliefs and medical information which he hoped would increase knowledge of savages and medicine in Europe. Retaining memory of the plant through the winter of 1715–16 and having passed 3 futile months in the field, he unexpectedly encountered the mature plant growing within striking distance of a

house. To his dismay, a Mohawk woman, whom he had been employing to search for it on her own, recognized it as one of their ordinary remedies, but on the strength of his account of the regard the Chinese had for it, she cured herself next day of an intermittent fever which had been plaguing her several months. She had prepared a simple infusion by soaking in water the root which she crushed between two stones. Moreover, at the sight of Jartoux's plate, which was sent up from Quebec at Lafitau's request, the savages recognized their plant of Canada. "And as we had in hand the different species, we had the pleasure of seeing a description so exact and in such just proportions with the plant, that it did not lack the least detail of which we had the proof before our eyes."

Lafitau published 2 years later his discovery of the American ginseng species, *Panax quinquefolium* L., in the now rare "Mémoire * * * concernant la precieuse plante du Ginseng, découverte en Canada," Paris, 1718. Dwarf ginseng or groundnut, *Panax trifolium* L., which is still collected by the Seneca of western New York, has the same Iroquois name. Both the Iroquois and the Chinese singled out the same feature, the bifid root, for naming their respective species. Lafitau held that the Iroquois (Mohawk) word Garent-oguen, composed of orenta, hips and legs, plus -oguen, bifid, and Ginseng derived from the Chinese, "looks like a man," were demonstrable parallels in evidence of the Asiatic origin of Indians, and he attributed their similarity to diffusion. Recent recordings of various dialects—degarądo'gą (M.), degaiɛ'do'gɛ (Oa.), diaiɛ'do'gɛ' (C.). djɛ',=, *or* djaɬ'' dogɛ' (S.)—also mean "crotched body," the spindled root resembling the hips and legs of a man.

In the same report Lafitau observed how easy it is, even for the Mohawks who distinguish between them, to confuse ginseng with its relatives of the Aralia family. The Mohawks of his day called wild sarsaparilla (*Aralia nudicaulis* L.), Tsioterese, "long root," and their descendants, djohde'rise. A third member he did not name but described; the modern Mohawks call it djohde'risegoowa, "great long root"; it is spikenard (*Aralia nudicaulis* L.) The latter two are generally used among the Iroquois in blood remedies and for colds, but the Caughnawagas of Lafitau's day ranked sarsaparilla among their vulneraries. Besides, like the modern Seneca, they used ginseng to purge babies on the cradleboard and as a stomachic; and the Huron and Abenaki, whom he says were one culturally, employed it for dysentary.

If the report of Lafitau's discovery and the arrival of the botanical specimen in Paris created a furore in the Royal Academy, at least in Canada there was no question about the value of the plant.

Throughout the summer of 1716 Indians enjoyed a lucrative business, digging the root and marketing it in Montreal. A year later a lieutenant of French infantry introduced its use among the Fox of Green Bay, Wis. Very soon the French began collecting it, with the help of Indian diggers, for export to China. There it was desired in such quantities that dried ginseng presently became an important article of commerce in Canada. At first, traders were able to buy at 2 francs per pound in Quebec and sell the root for as high as 25 francs in China. In the early stages of the trade, the Company of the Indies, who then controlled the trade, permitted the officers of their vessels to carry ginseng as a private speculation. But in 1751, when they perceived that these individuals were growing wealthy, the company reserved the trade for themselves. For a year thereafter the price rose steadily beyond 33 francs in Canada until, to meet the tremendous demand of the Rochelle merchants, an immense quantity was dug out of season, improperly cured in ovens and shipped to the French port, amounting in value to a half million francs. When part of this arrived in China the Canadian root acquired such a bad reputation that soon after 1754 the China market was virtually lost.[40]

Although the status of the ginseng trade when Kalm visited America is typical of colonial commercial interests during the eighteenth century, fortunately the same period witnessed the rise of the scientific spirit in Europe and America. European physicians and botanists coming to this country were inspired to collect New World flora and fauna for expanding the new systematic biology which was emanating from Linné in Sweden. Moreover, in England both the commercial and scientific interests in plants centered at the house of Peter Collinson, London merchant, whose importations from America enabled him to stir up enthusiasm for gardening; and Collinson's unflagging zeal as a letter writer made his address the international exchange for botanical information. In America, Philadelphia was the scientific capital of the Middle Colonies. On a neighboring farm lived John Bartram (1699–1777), who experimented with herbs and was influenced by Franklin to study botany seriously. He became Collinson's American correspondent, and in the course of their long relations, Bartram collected and shipped nearly 200 species of American plants and seeds, which Collinson introduced into botanical gardens of England. Subscription funds raised by Collinson enabled Bartram to travel widely through the country of the Delaware and Iroquois. Although Bartram fundamentally distrusted Indians, he made good observations of their customs on an expedition to Onon-

[40] Nash, George V., American ginseng; its commercial history, * * * etc. (revised and extended by Maurice G. Kains), U. S. Dep. Agr., Div. Botany, Bull. No. 16, revised ed., 1898; Kains, M. G., Ginseng * * * New York, 1909.

daga (1743),[41] but basically he was disinclined to publish. His botanical garden in Philadelphia, however, is a mute monument to his unrecorded knowledge of Indian plant uses, which were in part set down by Peter Kalm, Linné's student, who found Bartram charming but complained that he wrote too little. Through Collinson, Bartram and later Kalm met Cadwallader Colden (1688–1776), physician, surveyor, historian of the Five Nations, and politician, who, during a busy life in America since 1710, had nevertheless found time to employ Linné's classification for the plants of the New York colony. In correspondence Colden discussed the virtues of Indian remedies with Mitchell and Collinson in England, maintaining that common lard is a more trustworthy deterrent for rattlesnakes than the widely touted Seneca snakeroot (*Polygala Senega* L.).[42]

From as early as 1650 various writers had reported that Indians knew demonstrably powerful antidotes against rattlesnake bites. When traversing snake-infested country they constantly carried dried roots to chew and spit on their hands to repel the reptiles or to counteract the venom. Possibly several species were employed in different localities. The "true rattlesnake root" has been variously identified by Loskiel and the Moravians as *Polygala Senega* L., or as Virginia snakeroot (*Aristolochia serpentaria* L.), or as wild ginger (*Asarum canadense* L.), which the Senecas call snakeroot (oskwái'da'); however, Kalm reports that Bartram learned of the use of stoneroot or horse balm (*Collinsonia canadensis* L.) from Conrad Weiser, Mohawk-speaking interpreter for the Six Nations; while Charlevoix and that professional elk hunter of Pennsylvania, Phillip Tome, mention a yellow-flowered member of the aster family (compositae), which the latter calls oxwood, and describes as having a slender stem and limbs and yellow flower like the sunflower; but the modern Senecas of Allegany maintain that the "rattlesnake killer" (osígweǫ't odínyos) is either *Prenanthes alba* L. or *P. altissima* L., designating the latter the male and the former the female of the species.[43]

Colden was not alone in questioning the value of Indian remedies which had gained wide currency among colonists on the frontier. That the Dutch, Swedish, English, and French settlers had borrowed many wrinkles in herb therapy from the Indians in addition to the very rich

[41] Bartram, John, Observations * * * in travels * * * to Onondaga, etc., London, 1751.

[42] Earnest, Ernest, John and William Bartram, botanists and explorers, pp. 16, 34 ff., and 71, Philadelphia, 1940; Cadwallader Colden Papers, Coll. New York Hist. Soc., vols. 3, 4, 5, 7, 8, and 9.

[43] Van der Donck, Adriaen, op. cit., p. 178; The representation of New Netherland, 1650, p. 298; Jesuit Relations, vol. 59, p. 101; Loskiel, George Henry, op. cit., p. 114; Kalm, Peter, op. cit., pp. 105–106; Charlevoix, P. F. X., Journal of a voyage * * *, vol. 1, p. 244, 1761; Tome, Phillip, Pioneer life; or thirty years a hunter, 1854, Harrisburg reprint, p. 117, 1928.

medical folklore which they had brought with them from northern Europe is plain from the journal of Peter Kalm's Travels (1748–1751), already referred to, and the Materia Medica Americana (Erlangae, 1787) of Johann David Schoepf, the Anspach-Bayreuth surgeon who came over with Hessian troops during the Revolution and traveled westward during 1783 across Pennsylvania to Pittsburgh and the Ohio River as far as Kentucky, returning via Annapolis and Baltimore. It is not difficult to appreciate the belief in Indian remedies when such a pious man as Heckewelder, missionary to the Delaware and Shawnee in Ohio, testified that he had been cured of a stubborn rheumatism by Indian sweating and that "The wives of Missionaries, in every instance in which they had to apply to the female physicians, for the cure of complaints peculiar to their sex, experienced good results from their abilities." [44] In fact, so many Indian herbs had been reported by botanists and their uses as practiced by so-called Indian herb doctors included in herbals of the period (as witness John Bartram's "Descriptions, virtues, and uses of sundry plants of these northern parts of *America*; and particularly of the newly discovered *Indian* cure for *Venereal* Disease (*Lobelia sp.* L.)" (1751), and C. S. Rafinesque's "Medical Flora" (2 vols., Philadelphia, 1828–30)), that Dr. Benjamin Rush (1745–1813), the eminent physician of Philadelphia, decided to investigate the desirability of admitting Indian remedies to the pharmacopoeia. Having returned to Philadelphia in 1769 fresh from medical training in Edinburgh, Rush not only attracted wide attention for advocating a new "system" of medicine, but he soon joined the American Philosophical Society and began delivering papers on social issues. Among his first was an oration, delivered February 4, 1774, on the diseases of the American Indians,[45] a tour de force of reasoning based on a few facts taken from Lahontan and Charlevoix, some personal observations of pulse rates taken on Indians visiting his city, and evidence furnished by persons of experience with Indians, notably Dr. Edward Hand, surgeon of the 18th regiment at Fort Pitt. Nevertheless, lacking personal observations, Rush maintained that Indian society was adapted to a vigorous mode of life and, therefore, he discussed the etiology of their diseases in terms of birth, diet, division of labor by sexes, and common customs—a rather advanced viewpoint ethnologically. Their pediatrics—cold baths, cradleboard, and 2-year lactation—he found conducive to survival of the fittest, and their mixed diet, periods of alternate rest and exercise, late marriage, and matura-

[44] Heckewelder, Rev. John, History * * * of the Indian nations * * *, p. 229, Philadelphia, 1876.

[45] Rush, Benjamin, an inquiry into the natural history of medicine among the Indians of North America, and a comparative view of their diseases and remedies with those of civilized nations. Together with an Appendix, containing proofs and illustrations. 118 pp., Jos. Cruikshank, Philadelphia, 1774.

tion of men and women, he thought productive of a hardy race whose women suffered few miscarriages and endured childbirth unattended in a secluded hut and whose men inured to warfare and dancing were vigorous and seldom neurotic. Himself an advocate of the use of special remedies for each disease, Rush questioned the value of Indian specifics on the grounds of secrecy—such medicines cease to work cures when the formulae are known—and the undifferentiated nature of Indian society which did not permit a hunter-warrior to give his entire, abstracted attention to herbalism. He insisted that Indians fail with the wrong remedies; and he questioned the antivenereal qualities of *Lobelia sp.* L., *Ceanothus sp.* L. (New Jersey tea), and *Ranunculus* (?) which Kalm had reported. Dr. Hand had informed him that the Indians around Fort Pitt employed a plentiful decoction of the pine tree, but that they sometimes died. He noted that the Indians had acquired from the whites the art of phlebotomy, which he dogmatically defended in his own practice, and in contrast he concluded, as if to purge the materia medica of his time, "We have no discoveries in the materia medica to hope for from the Indians of North America."

Despite this judgment Rush was still open to conviction a number of years afterward. On May 2, 1791, he transmitted a list of questions concerning matters of health and medicine among the Indians through the Secretary of War, to be asked by Colonel Pickering on his mission to the Six Nations.[46]

To summarize this discussion of white borrowings from Indian medicine, we offer a partial list of the more important medicinal plants used among the Iroquois. Notwithstanding Rush's prediction to the contrary, some of these have been retained in the U. S. Dispensatory: Maidenhair fern (*Adiantum pedatum* L.), ground pine (*Lycopodium obscurum* L.), white pine (*Pinus strobus* L.), hemlock (*Tsuga canadensis* (L.) Carr.), Indian turnip (*Arisaema triphyllum* (L.) Schott.), sweet flag (*Acorus calamus* L.), in singing; Indian poke (*Veratrum viride* Ait) for catarrh; bellwort (*Uvularia perfoliata* L.), blue flag (*Iris versicolor* L.), sweet gale fern (*Myrica asplenifolia* L.), used by Mohawks for toothache (Kalm); white oak bark (*Quercus alba* L.), an astringent; slippery elm (*Ulmus fulva* Michx.) in childbirth; wild ginger (*Asarum canadense* L.) in fevers; and the dyeplant, pokeweed (*Phytolacca americana* L.). Several members of the crowfoot family were borrowed: Goldthread (*Coptis trifolia* (L.) Salisb.), goldenseal (*Hydrastis canadensis* L.), Canada anemone (*Anemone canadensis* L.), and black cohosh, snakeroot (*Cimicifuga racemosa* (L.) Nutt.) (pl. 4, fig. 1). Mayapple (*Podophyllum peltatum*

[46] Pickering Papers (historical index), Coll. Massachusetts Hist. Soc. Boston, ser. 6, vol. 8, p. 233; Pickering Papers (ms.), vol. 61, folios. 183, 302 [with answers]. See also Rush, Benjamin, *in* Dictionary Amer. Biogr., vol. 16, pp. 227–231.

L.), blue cohosh or papoose root (*Caulophyllum thalictroides* (L.) Michx.), sassafras (*S. officinale* Nees & Eb.), and bloodroot (*Sanguinaria canadensis* L.) are well known. Indian physic or Bowman's root (*Gillenia trifoliata* (L.) Moench.) (pl. 3, fig. 2); avens (*Geum canadense* Jacq., *G. rivale*, and *G. strictum* Ait.) in fever and diarrhea; cherry (*Prunus serotina* Ehr.) bark for coughs (pl. 4, fig. 2); yellow wild indigo (*Baptisia tinctoria* (L.) R. Br.) and cranesbill (*Geranium maculatum* L.) for summer complaint were common colonial remedies. Sumac (*Rhus typhina* and *glabra* L.), New Jersey tea (*Ceanothus americanus* L.), basswood (*Tilia americana* L.), and leatherwood (*Dirca palustris* L.) bark for wounds, and willow herb (*Epilobium angustifolium* L.) were not so widely known.

The ginseng family—*Panax quinquefolium* and *P. trifolium* L., spikenard (*Aralia racemosa* L.), and wild sarsaparilla (*A. nudicaulis* L.)—have been discussed, as well as waterhemlock (*Cicuta maculata* L.). Angellica (*A. villosa* (Walt.) BSP. and *A. atropurpurea* L.) for respiratory ailments is less known than several species of dogwood: *Cornus florida* L. for arrows, spoons, and weavers' tools (Kalm), and red osier dogwood (*C. stolonifera* Michx.), "green osier" (*C. alternifolia* L. f.), and kinnikinnik (*C. Amomum*) as emetics; while Prince's pine (*Chimaphila umbellata* (L.) Nutt.), trailing arbutus (*Epigaea repens* L.), and wintergreen (*Gaultheria procumbens* L.) for blood and kidneys were used by Indians and settlers alike in western New York.

Likewise, ague weed (*Gentiana quinquefolia* L.), two species of the dogbane family (*Apocynum androsaemifolium* L. and A. *cannabinum* L. [Indian hemp]) for fiber and "bloody flux" (Kalm), and stoneroot (*Collinsonia canadensis* L.) were formerly much used by Indians and are still demanded by traders. Indian tobacco (*Nicotiana rustica* L.) is still grown by the Iroquois, and hare figwort (*Scrophularia lanceolata* Push.) for blood, and Culver's root (*Veronica virginica* L.), a cathartic, are the great medicines of the Allegany Senecas. Partridge berry (*Mitchella repens* L.) or "squaw vine," feverwort (*Triosteum aurantiacum* Bicknell), elder (*Sambucus canadensis* L.), a whole pharmacy in itself whose proper use the Iroquois understand, and several species of *Lobelia*, the great "love medicine" of the Iroquois, for which Kalm advanced antivenereal qualities, enter into many formulae.

Of the many species of the aster family (Compositae) that the Iroquois employ, some were naturalized from Europe, but use of two groups was acquired very early by the whites: Joe-Pye weed (*Eupatorium maculatum* L. and *purpureum* L.) for kidneys, and thoroughwort (*E. perfoliatum* L.) for colds and fever (pl. 5, fig. 1); and rattlesnake root (*Prenanthes alba* L. and *altissima* L.). Life in the colonies

demanded that the settlers rely on a greater number of native plants, or Indian herbs, than were ever introduced into Europe to supplement the few garden herbs which they brought with them.

Species that the colonists had introduced for their gardens and undesirable weeds unwittingly brought here were either traded or soon escaped to the Indian country, where new uses were devised for them. Both Lafitau and Loskiel agree that the Indians were eager to learn the remedies of the white physicians, and because of the lack of botanical literature among Indians one cannot decide what uses for native plants were acquired from Europeans. Nevertheless, we can be certain that specifics and formulae based on species that are known to have been naturalized from Europe were devised during the contact period. In 1748 Kalm observed mullein (*Verbascum thapsus* L.), which the Swedes called wild tobacco, growing around Philadelphia; and a half century later it had spread in great abundance to newly cleared fields and burnt-over areas in remote parts of the country, where sometimes not a plant was found in 100 miles.[47] Iroquois use of mullein leaves in poultices for swellings and sores either was acquired from the whites or dates from the eighteenth century. In the case of *Chenopodium album* L. (lambs quarters, or pigweed), which Kalm noted growing on dunghills, streets, and grain fields around Philadelphia in 1748, the Mohawks have commemorated its introduction by naming it skanadanʏʊm'we, "loves the village," because it grows along paths and roads of settlements. A similar Iroquois name, deya'oowǫ' (S.), diyuhahǫ'wih (C.), "covers the road," marks the naturalization of broadleaved plantain (*Plantago major* L.). My Iroquois informants recommend it as a poultice for skin injuries and they would be surprised to learn that their forebears had regarded it as an interloper. Kalm, writing in 1748 of his visit to John Bartram, says:

> Bartram had found this plant in many places on his travels, but he did not know whether it was an original American plant or whether the Europeans had brought it over. This doubt had its rise from the savages (who always had an extensive knowledge of the plants of the country) pretending that this plant never grew here before the arrival of the White Men. They therefore gave it a name which signified the (Englishman's) foot, for they say that wherever a European had walked, this plant grew in his footsteps.[48]

Readiness of the Iroquois to expand their culture is moreover apparent from the following adventive plants that were added to their materia medica during the contact period: Yellow dock (*Rumex crispus* L.), bitter dock (*R. obtusifolius* L.), heartweed (*P. persicaria* L.), milk purslane (*Euphorbia maculata* L.), mallows (*Malva rotundifolia* L. and *M. moschata* L.), St. John's wort (*Hypericum*

[47] Kalm, Peter, op. cit., p. 40; Pursh, Frederick, Flora Americae septenrionalis, 2 vols., p. 142, London, 1814.

[48] Kalm, Peter, op. cit., p. 64.

perforatum L.), Queen Anne's lace (*Daucus carota* L.), catnip (*Nepeta cataria* L.), and peppermint (*Mentha piperita* L.). To the aster family belong the greatest number of important introduced herbs. Of these, elecampagne (*Inula helenium* L.), consumption medicine, is domesticated and as an escape on abandoned settlements "grows like sunflower" (gawe''ǫsoontha' (S.)) (pl. 5, fig. 2), while common yarrow (*Achillea millefolium* L.) along the paths "grows like hemlock" (ganɛ''dǫtha'), with mayweed (*Anthemis cotula* L.) for summer complaint, and tansy (*Tanacetum vulgare* L.) with its "powerful odor" (gahųmda'gerasgoowa (M.)) for sick headache; and to complete the list add burdock (*Arctium minus* (Hill) Bernh.) for body pains, dandelion (*Leontodon taraxacum* L.) present since Kalm's day, and useless devil's-paintbrush (*Hieracium aurantiacum* L.) which the birds disseminated from Canada during the lifetime of the late John Armstrong (Seneca).

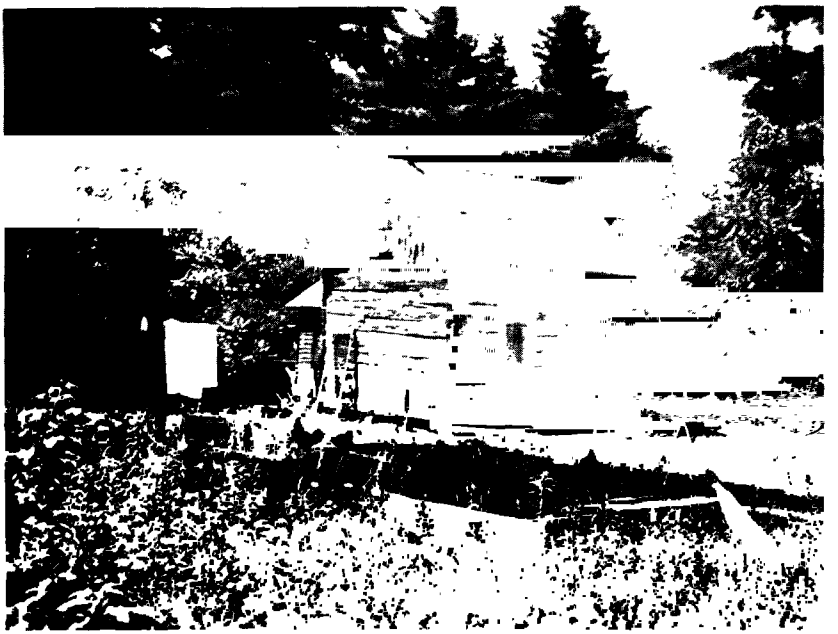
In general these introduced plants bear Iroquois names betokening their diffusion during historic times, or they are named after native plants which they resemble. Names of new plants differ markedly more than old plant names. Their uses, when not actually acquired simultaneously or later from herbals, are based on analogies with older plants. Significantly, they are not employed in ancient ceremonies, and frequently are not used at all.



1. MISSION OF SAINT FRANCOIS-XAVIER AT CAUGHNAWAGA P. Q., ON THE ST. LAWRENCE, WHERE J. F. LAFITAU DISCOVERED GINSENG IN 1716.



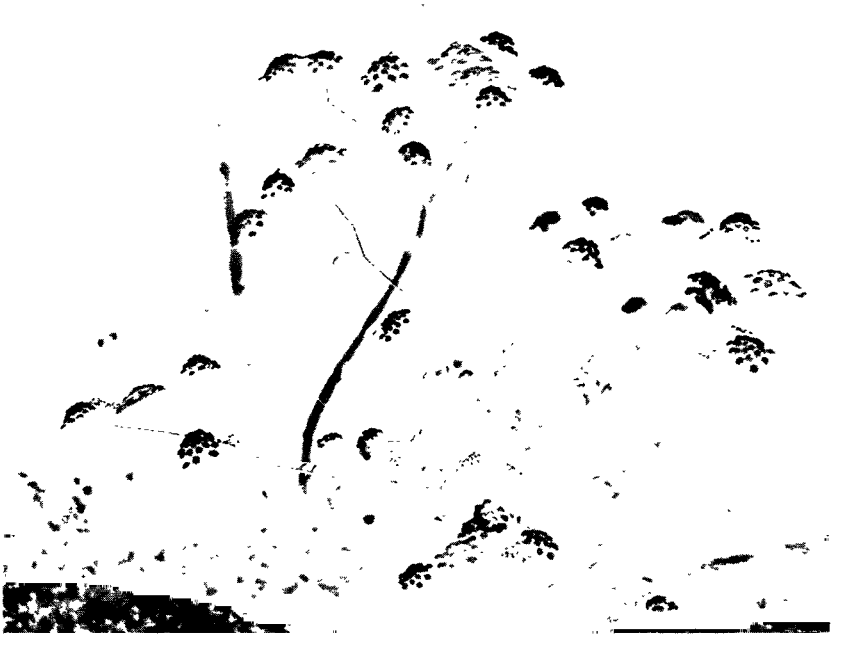
2. THE ALLEGHENY RIVER AND UPLAND FOREST OF THE SENECA COUNTRY IN SOUTHWESTERN NEW YORK



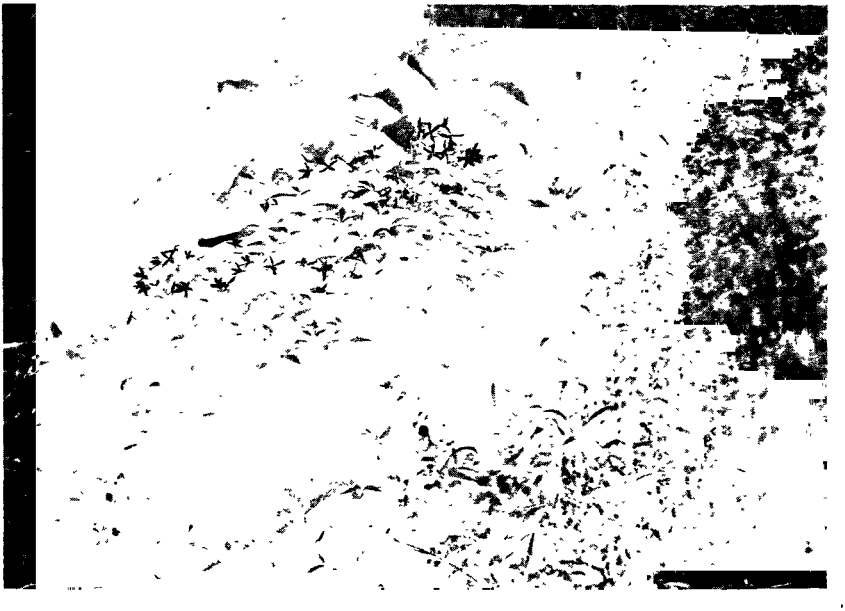
1 LOG HOUSES OF WHITE PINE SUPPLANTED ELM BARK HOUSES IN 1800



2. AN ONONDAGA HERBALIST OF SIX NATIONS RESERVE ON GRAND RIVER ONTARIO, WHO PRACTICES AN ANCIENT ART



1 ONDACHIERA, THE DEADLY WATERHEMLOCK (CICUTA MACULATA L.), OF IROQUOIS SUICIDES.



2 INDIAN PHYSIC OR BOWAN'S ROOT (GILLENIA TRIFOLIATA (L.) MOENCH) TRANSPLANTED INTO A SENECA HERBALIST'S GARDEN



1 DWIGHT JIMMERSON (SENECA) COLLECTS FOR RHEUMATISM, BLACK COHOSH (CIMICIFUGA RACEMOSA (L.) NUTT.) WHICH HE SELLS TO WHITE PEOPLE



2. CHAUNCEY J. JOHN SENECA HERBALIST, DRIES BARK OF WILD CHERRY (PRUNUS SEROTINA EHR.) BEFORE TRADING IT TO DRUG MANUFACTURERS



1. BONESET OR THOROUGHWART (EUPATORIUM PERFOLIATUM L.) FOR FEVER AND COLDS WAS ACQUIRED EARLY BY THE WHITE SETTLERS IN NEW YORK.



2. JEMIMA GIBSON (CAYUGA) FINDS ELECAMPAGNE (INULA HELENIUM L.) GROWING AS AN ESCAPE AT CHIEF'S WOOD ON GRAND RIVER.

THE STUDY OF INDIAN MUSIC

By FRANCES DENSMORE
Collaborator, Bureau of American Ethnology

[With 6 plates]

INTRODUCTION

The invention of the recording phonograph opened a new era in the preservation and study of Indian music. Previous to that invention it had been necessary for students to write down Indian songs by hearing them, a proceeding which involved many difficulties. Dr. Theodor Baker, of Germany, collected songs in that manner in 1880, and Dr. Franz Boas did his remarkable work among the Central Eskimo in 1883–84, the resulting publication (6th Ann. Rep. Bur. Amer. Ethnol.) containing more than 20 Eskimo songs with a description of their melodic form. Ten Omaha songs were presented in a paper by Miss Alice C. Fletcher entitled "The 'Wawan' or Pipe Dance of the Omahas," published in 1884 by the Peabody Museum of American Archaeology and Ethnology. When the phonograph became available, Miss Fletcher used that method of collecting Indian songs, and her name is forever linked with the study of Indian music. The phonograph that she used among the Omaha, about 1890, was later transferred to the Bureau of American Ethnology. This instrument, which I saw in Miss Fletcher's home, had a high mandrel, at least 6 inches above the plate of the machine, and she said it was a sturdy instrument as it had "traveled across the prairie in the wagons of the Indians and even rolled down hill without injury." Ninety songs recorded among the Omaha were transcribed by John Comfort Fillmore and contained in Miss Fletcher's book entitled "A Study of Omaha Music with a Report on the Structural Peculiarities of the Music by John Comfort Fillmore,"[1] published by the Peabody Museum in 1893. Twelve aluminum disk records of Arapaho, Kiowa, Caddo, and Comanche songs, collected by James and Charles Mooney in 1894 and marked "E. Berliner's Gramophone, pat. Nov. 8, 1887, May 15, 1888," are in the possession of the Bureau of American Ethnology.

[1] Peabody Mus. Amer. Archaeol. and Ethnol., Harvard Univ., Pap., vol. 1, No. 5, 1893.

It is believed that the first printed account of the use of a phonograph among Indians was that of Jesse Walter Fewkes, published in 1890. In April of that year Dr. Fewkes took a phonograph operated by a treadle among the Passamaquoddy Indians in Maine and recorded their language and songs. Sixteen items were recorded, five of which were songs. Later he recorded Zuñi and Hopi songs, using a phonograph with storage batteries, but he considered this less satisfactory than the instrument with a treadle. These songs were transcribed and studied by Dr. Benjamin Ives Gilman. With his keen appreciation of advancement in science, Dr. Fewkes was also a pioneer in the recording of Indian songs on disks, in the field. Assisted by Dr. John P. Harrington he thus recorded 11 Hopi songs. (See 43d Ann. Rep. Bur. Amer. Ethnol., p. 5, 1925–1926.) A complete recording equipment was installed by a piano company and operated by a professional sent for the purpose, and the disk records were released through commercial channels.

It is impossible to mention all the ethnologists and musicians who have included Indian music in their studies, but each has contributed, in some way, to the development of the research.

As this paper is to trace the development of my own work on Indian music, let me first express my appreciation of the inspiration and aid extended to me by these pioneers in a unique and highly specialized field of research. Miss Alice C. Fletcher's work was called to my attention a year or two before the publication of her book on Omaha music, and with the encouragement of Professor Fillmore, whose acquaintance I had made, I wrote to Miss Fletcher, telling of my interest in the subject. If she had been less gracious in her response it is probable that I would not have taken up the study of Indian music. My interests were entirely musical as I was teaching piano and lecturing on the Wagnerian operas. Indian music attracted me only as a novelty, but in 1895 I added it to my lecture subjects, presenting Miss Fletcher's material with her permission. I availed myself of every opportunity to hear Indians singing at fairs and other exhibitions, and began a systematic course of reading on the history and customs of the American Indians. About 1901 I wrote down a Sioux song that was sung by Good Bear Woman, a Sioux living in a small Indian village near Red Wing, Minn. Among the attractions at the Louisiana Purchase Exposition in St. Louis, in 1904, was the old Apache warrior Geronimo. I stood behind him and noted down a melody that he hummed as he printed his name in careful letters on cards to sell to passersby.

Every year, on June 14, the Chippewa at White Earth, Minn., hold a celebration with much singing and dancing. I attended this celebration in 1905 and had my first impression of Indian dancing on a

reservation. The Chippewa are excellent singers, the costumes were picturesque, and the green of the prairie was a lovely background to the picture. Hour after hour I sat beside the dance circle, becoming more and more impressed with the idea that I must record Chippewa songs as Miss Fletcher had recorded the songs of the Omaha. Two years later I recorded Indian songs for the first time, from some of the same singers. The June 14 celebration was attended again, in 1907, and afterward, using a borrowed recording phonograph, I recorded songs sung by Big Bear and other Chippewa friends. Later I stopped at Onigum, on the Leech Lake Reservation, and the visit was at an opportune time. Flat Mouth, the chief of that band of Chippewa, lay dying, and the medicine men were treating him according to the customs of the Grand Medicine Society (Midewiwin) of which he was a member. This took place about a mile from the agency and I was the only white person present. The Indians knew I was there but made no objections, and I heard songs that were sung only on such an occasion.

Prof. William H. Holmes, then Chief of the Bureau of American Ethnology, Smithsonian Institution, in 1907 allotted $150 for the recording of Indian songs. I bought an Edison Home Phonograph, the best recording equipment available at that time, and returned to the Chippewa agency at Onigum to begin my work. The Indians remembered my presence there at the time of Flat Mouth's death, and the medicine man who was in charge of the ceremony recorded many of his best songs. Several others recorded songs of the Grand Medicine and drew the pictures that represent the words of these songs. I tested the accuracy of this system of mnemonics by showing the pictures to members of the Grand Medicine Society at White Earth, a few weeks later, and they sang the same songs.

Later in the same year, with a further allotment of funds, I went to White Earth, Minn., and continued my work. One of the most important informants was an aged man named Maingans (Little Wolf), a member of the Midewiwin.

A few weeks after this work at White Earth I went to Washington for the first time, and gave a lecture on Indian music before the Anthropological Society of that city. Maingans and several other old Chippewa were in Washington on tribal business and consented to enact a portion of a Grand Medicine ceremony, singing the songs. They did this in all sincerity and it was received with respect, but Maingans was severely punished when he returned to the reservation. He was not allowed to enter the lodge when the Midewiwin held its meetings the following June. His wife died, and this was attributed to his enacting part of a native religious ceremony for the pleasure of white men. The Indians did not blame me, and the

responsibility was placed entirely upon him and the other Chippewa who took part, but the regret remained. For that reason I have often refused to take material that is surrounded by superstition. I tell the Indians that I am trying to preserve the material so their children will understand the old customs, and that I do not want them to worry or be unhappy after I have gone. Sometimes this allays their fears and they are willing to talk freely, but I would rather miss some information than cause such distress as that of my old friend, Maingans, the Chippewa.

RECORDING EQUIPMENT

The phonograph I bought was a small machine and the Bureau in 1908 replaced it with a Columbia graphophone. Home recording was at the height of its popularity and this machine was made to meet the demand. I was also supplied with several special recorders which I tested with various types of voices and marked for the use to which they were best adapted. The galvanized-iron recording horn sent with this equipment was the best I have ever used. I have since tried many others, but none has produced the same quality of tone. This equipment is still in excellent order and I used it in recording Zuñi songs in 1940.

During the years since this was purchased I have tried one type of recording apparatus after another, as they have been placed on the market. My next equipment was a 4-minute Edison phonograph, used for the first time among the Ute in 1916. This had a metal frame, increasing the weight. The cylinder was longer, making it possible to record more singing, but the thread was finer and the little ridges on the cylinder sometimes broke down with repeated playing of the record. This equipment was used only in Utah and in North Dakota, when recording songs of the Mandan and Hidatsa in 1918. It had several recorders but I could not distinguish between the quality of their recordings.

In 1924 I began the use of an electric dictaphone and have used one at intervals ever since. It was used when recording the songs of the Tule Indians in Washington, the Seminole in Florida, the Winnebago in Wisconsin, the Omaha in Nebraska, and the songs of Santo Domingo Pueblo, recorded in California. For recording on the reservations I have used a dictaphone operated by a storage battery, but for recent work among the Omaha I used a 1941 model dictaphone, adapted to either direct current or alternating current. The type of recording apparatus varies with the circumstances under which the work is done. The ordinary dictaphone is not a precision instrument and alternating current is not always the same. The difference in current may cause a difference of a half tone, or even

a tone, in the pitch of a song as played on different days, but the transcription corresponds to the final checking of the record. The dictaphone is not intended to reproduce musical sounds and the quality of tone is less satisfactory than that of a phonograph.

An advantage of the dictaphone is that the change from recorder to reproducer is made with a single motion, whereas in a phonograph it is necessary to detach the horn, loosen a screw, take out the recorder, insert the reproducer, tighten the screw and connect the horn. Frequently an Indian wants to hear the record he has made, or it is desirable to hear the recording for some other reason, and these motions take an appreciable time. A disadvantage of the dictaphone is that the horn is small, as it is intended for a man at an office desk. If the Indian becomes interested in his singing and moves the horn away from his mouth the record becomes faint. It is sometimes necessary to hold the horn in position while the Indian sings. His position is easier to maintain when he sits in front of a phonograph horn that is swung from a crane. Another advantage of a phonograph horn is that it will, if desired, record the sound of as many as four singers, carefully grouped. It will also record the sound of a percussion instrument as accompaniment.

Songs are recorded best when the phonograph is not tightly wound. It is customary to rewind the phonograph with a few turns of the crank between recordings to maintain this tension of the springs. This precaution is scarcely necessary, as a test of the Columbia graphophone showed that the speed remained the same for about 15 minutes, after which it dropped rapidly. An uneven action of the motor distorts the speed and pitch of the record. Thus Dr. Fewkes described in conversation some of the difficulties he encountered with his first phonograph, which was operated by a foot treadle. If he became interested in the singing he moved the treadle faster, increasing the speed and raising the pitch. Sometimes he moved the treadle slower, with the opposite effect.

The records on the phonograph and dictaphone are made by the "vertical path," often called the "hill and dale" method, in which the depth of the groove varies with the loudness of the tone. The late Emile Berliner expressed the opinion that this method of recording was best adapted to my work. He became interested in my work in 1913 and a pleasant acquaintance continued almost to the time of his death. The process of recording on disks was advanced by Mr. Berliner in 1887. Records on disks are made by the "horizontal path," the groove made by the recording needle being of uniform depth throughout its length and varying from side to side. This is the only method used commercially on disks at the present time, but recording on disks by the vertical path has been developed in the

laboratories of the Bell Telephone Co. Concerning this recording on disks, Dr. Leopold Stokowski stated in 1935 in correspondence, "The quality of the recording was extremely high."

During the World's Fair in Chicago in 1933 I recorded Indian songs on disks, using a Fairchild apparatus courteously placed at my disposal by Mrs. Laura G. Boulton and Dr. George Herzog. The records were made on aluminum disks. This apparatus uses a microphone and makes possible the recording of groups of singers. It was desired to obtain records of typical group singing by Sioux, and five singers—three men and two women—were selected from those taking part in exhibitions at the fair. I also obtained examples of typical singing by women, with their peculiar tone production. Navaho songs were recorded by two members of that tribe, singing in unison while beating a small drum.

Many of my cylinder recordings were transferred to aluminum disks in the laboratory of Dr. C. E. Seashore at the University of Iowa. This work was done in 1934 and the original tone was admirably preserved. Dr. Seashore's courteous interest has extended over a period of many years and is acknowledged with deep appreciation. A considerable number of my cylinder recordings have also been transferred to composition disks.

Mention may here be made of the interest shown by the Indians when they first hear recordings of their voices. One woman said, "How did the phonograph learn that song so quickly? That is a hard song." Another woman said, "The phonograph seems to be blowing feathers," referring to the shavings of the recording. Such primitive Indians are not met so frequently now as in the earlier years of the work.

WORK IN THE FIELD

Before describing the recording of Indian music in the field, let me acknowledge with appreciation the courtesy that has been extended to my work by the Commissioners of Indian Affairs, the representatives of the Indian Office in the field, and the missionaries of Protestant and Roman Catholic churches on the reservations.

The first endeavor, after presenting my credentials to the superintendent (formerly called the agent) and arranging for a place to stay, is to find a competent interpreter. It is not advisable to employ the agency interpreter nor one connected with a mission, as they use the current vocabulary of those institutions. Their purpose is to convey an idea and, beyond the simplest transactions, my work requires a different type of man or woman. I must have an interpreter who can think in Indian and translate the native idioms into pure, grammatical English. My best interpreters have been

graduates or former students of Hampton Normal and Industrial Institute and the Carlisle School. These men had a literary use of English because they were away from its vernacular use for so many years. Valuable aid was also given by the Rev. Clement H. Beaulieu, a Chippewa clergyman of the Episcopal church who studied the subtle meanings of the Chippewa language as he studied Greek. Much time is required in working out the understanding of a word in the Indian mind, and the interpreter must be patient as well as painstaking when translating the words of songs or any information that lies close to the finer phases of Indian thought. An exact translation of the Indian idiom reveals the native poetry in the words of the songs.

It was particularly hard to find a competent interpreter among the Seminole in Florida, as shown by the following incident: A certain dance was designated as the Two-headed Dance. On being questioned further the interpreter said he meant that the dancers "headed two ways," and described the motion of the dancers around the man who is shaking the coconut-shell rattle. They move in a circle until they reach their starting point, then stand still a minute before reversing the motion, moving in the opposite direction and singing another song. The name of the dance was recorded as the Two-direction Dance. Another dance was called the Screech Owl Dance and many songs were recorded with that title. Panther said it was also called the Prairie Dance, saying this was an "off-hand name" given it by the white people. He said the Seminole were to dance at a certain exhibition and the manager gave it that name. "There was no reason for the change but white people understood that word 'Prairie.'"

Robert Higheagle, my interpreter on the Standing Rock Reservation in North Dakota, was a graduate of Hampton Institute as well as of the business department of Carnegie College. I could send him away for a day, on horseback, and he would "bring back his man"—not literally, but the man would come in his wagon the next day. After such a quest, Brave Buffalo, a distinguished medicine man, came to the agency and recorded his best songs. Attached to the band of his hat was a whistle which showed that he was on his way to attend a patient. He excused himself to go and see the sick person but returned later, as he promised. It was my custom to type my material and ask Higheagle to look it over. Thus I wrote a brief account of the life of Sitting Bull, in connection with his personal songs, and asked Higheagle to read it. He studied the material and then said "You have written that Sitting Bull returned from Canada. I think we had better say that he *was* returned, for the soldiers brought him back." When an interpreter uses the pronoun "we" I

know that the work is his as well as mine, and that he is giving the best that is in him.

The ideal place for recording Indian songs is a detached building which is not so isolated as to give an impression of secrecy nor so conveniently located that Indians will linger around the door. The building should be near the agency and trading post, so the Indians can attend to business if they wish to do so. This was important in the old days when they often came 25 miles or more on horseback. Such an ideal "office" is rare, but the superintendents of the reservations have always given me the best facilities at their disposal. I have recorded in an agent's parlor and in his office on a Saturday afternoon, and also at a Protestant mission. I have even recorded in a school laundry, with the tubs pushed back against the wall, and in an agency jail that was not in use at the time. A tar-paper shack was my office for more than a month on the Dakota prairie when the temperature in similar shacks was 116—there was no shade for miles around.

I remember with queer affection an office at Fort Yates, N. Dak., that had been part of the kitchen of the old fort. Subsequently it had been used as a coal shed, and it had neither door nor windows when I took over. The agent let a prisoner from the guardhouse help me fix it up and he suggested boring holes in the floor to let the water run through, when the floor was cleaned. He made steps, rehung the door, and nailed window sash over the openings, and I pasted paper over the broken plaster and used packing boxes as tables. For many weeks I used that office, and the Indians felt at home there, which is important. I stayed until the weather was bitter cold and the snow was piled high around the door. A little stove kept the place warm and I nailed a blanket over the door after entering, in order to keep out the bitter wind that blew down the Missouri River. One trial was that the mice did not move with the soldiers and their descendants had populated the building. They frisked around the floor and hid behind the paper on the wall. Once I found one under my typewriter when I came back at noon.

Among the Sioux who recorded songs in this office was Śiya′ ka (pl. 1), a particularly fine man, who recorded 29 songs, including songs of the Sun Dance, the warpath, and the buffalo hunt.

Many hundreds of songs have been recorded in schoolrooms during the summer vacation and in the homes of Indians. Henry Thunder, a Winnebago, refused to sing unless he could record in a grove, where he could see in all directions and be sure that no one would overhear him (pl. 2). I have recorded in a hospital, when a singer was able to sit up long enough to sing, and in the issue room of an agency, with its meat block and boxes, in the warehouse of a bridge company, and

in the little store of a Northwest Coast Indian, with whaling equipment of various sorts on the walls. There was a fine pair of floaters that I wanted to buy, but one morning when I asked for them the Indian said that someone came for them the night before, saying that a whale had been sighted. He said the floaters belonged to the whole village and anyone might call for them.

It is a rare combination of circumstances if I have a comfortable place to stay, an interpreter, singers, and a place to record all at the same time. Let us suppose that such ideal conditions exist, that the equipment has arrived in perfect order and been set up in an "office," that the singer is willing to sing, and the interpreter is seated beside him. Perhaps the man wants to smoke before he sings, which causes a slight delay. I usually ask the brand of tobacco that is popular in the tribe and provide a package which is duly presented at this time. I pay the singers in cash at the end of each day, and sometimes at the close of each song. An argument always arises as to the price, and I explain that I have the same price in each tribe for general songs, paying a higher price for certain classes of personal songs. It is hard for an Indian to understand why a song that was worth a horse in the old days should be recorded for the small price that I pay. A Sioux once offered to record a song that would break the drought. He said the dry summers would not have occurred if the Government had let the Indians sing their rain songs. He said the song would "work" for me as well as for an Indian, and he wanted $50 for it. According to him, the song was cheap at that price. Needless to say, I did not record the song and the drought continued.

If the Indian singer does not understand or speak English, the negotiations must be entrusted to the interpreter. He must explain that the history and origin of the song and the meaning of the words is included in the price of recording, unless there is a long legend or extended information, for which he will be paid by the hour. The interpreter explains that different verses of a song do not count as separate songs, neither are recordings of the same tune with different words paid for as separate songs. The Indian is told that he must not record songs that differ in only a few tones and expect pay for each recording. If a long series or a cycle of songs is under consideration, he is told to select the songs with the most interesting words or melody. This understanding is necessary, as a series may comprise a very large number of songs, and it is easier for the Indian to sing them all in sequence. There is little variety in such series, and it would be impossible, as well as unnecessary, to transcribe them all. The Indian is also instructed to sing the song through a certain number of times and then pause. Without this precaution the recordings would be almost impossible to separate.

When all these matters have been settled, the singer is shown how to sit in front of the horn, and to sing into it from the proper distance. If a dictaphone is used he must be shown how to hold the horn, pressing the upper edge against his upper lip. He is also told that he must sing in a steady tone and not introduce the yells and other sounds that are customary to Indian singers. The recording is not intended to be realistic, but to preserve the actual melody.

Indians rarely sing alone and generally have a percussion accompaniment. A medicine man may sing alone when treating a sick person, and under certain circumstances a man may sing his personal song at a gathering, but as a rule Indian singing may be called ensemble music. For this reason it is hard for one man to sing alone and to record his song without the support of a drum or rattle. The sound of an Indian drum does not record well, and I substitute a pasteboard box, struck with a small stick, which gives percussion without resonance. The singer soon learns to use it, holding it near the horn if the sound is to be recorded and farther away if it is only for his own assistance in singing. I may record two or more renditions with the percussion audible in order to preserve the relative rhythms, and then have one or two renditions with the accompaniment inaudible so the melody can be transcribed more easily. In some songs the meter of the drum is different from that of the voice, or the rhythm of the drum may be peculiar, and in such instances I am careful to obtain recordings in which the drumbeat is clear throughout the song. When the record is transcribed, the sound of the voice is excluded when determining the beat of the drum, and the sound of the drum is excluded when recording the voice; then I listen to the two together and check the result. In ordinary songs, such as the songs of games and social dances, the drum is continuous and steady and I may not make any record of it. Instead a notation is made in my notebook such as "drum in quarters exactly with the voice."

The sound of an Indian rattle can sometimes be recorded in order to obtain a record of the rhythm, but pounding on the pasteboard box is generally substituted for a rattle when songs are recorded. The Indian usually wants to try making a record with the accompaniment of the rattle but is soon satisfied that it is not practical with my equipment. Occasionally, he wishes to shake the rattle at his side, without trying to record it. Circumstances vary and there is no inflexible rule of procedure.

When a song is recorded, the cylinder box is marked with the singer's name and the number in his sequence, such as Red Weasel 10 or Brave Buffalo 20. At the beginning of my work I assigned a catalog number to each song when it was recorded and sent all the records to the Bureau of American Ethnology, but this was changed

after about 200 songs were recorded and I assigned catalog numbers only to the records that had been transcribed in notation. The others are studied but not sent to the Bureau. They may be almost like the songs that are transcribed, or they may be "seconds" that, in my opinion, are not worth preserving.

A singer may want to hear songs of other tribes, and I always carry a few discarded cylinders for that purpose. The type of melody differs in various tribes, and the Indian listens attentively, as one musician to a performance by another. I never use recordings in this manner, however, if the original singer objects to that use of his songs. Ordinary dance songs are sufficient for the purpose.

It is unsatisfactory to ask an Indian to give an "audition" of a song, to find out whether I want to record it. Strange as it may seem, his first rendition is usually the best, and this should be recorded. Instead of asking him to sing the song, I ask him to "go over it carefully in his mind until sure that he remembers it correctly." The room is quiet and he "thinks" the song, or hums it under his breath, probably tapping the time with one finger. A blank cylinder has been put in place and when he signals that he is ready the recorder is dropped and he records the song. It is many years since the old men have sung the old songs and the record must be made while the recollection is clear. A slight disturbance or delay might mean the loss of the song.

Psychology enters largely into the work of obtaining the old Indian songs. The singer must always be kept at ease. This is essential to success, and one must learn when to urge a singer and when to let him relax. Care must be taken that the form of a question does not suggest an answer. Through faulty questioning a person could obtain astounding statements from an Indian, as he might not understand the question or might be too polite to differ with the questioner.

An Indian may be willing to tell what is desired and not know how to express it. Sometimes one will question an Indian for a long time and the Indian will leave out the things one wants most to know; then he will suddenly give the whole information without realizing it, or in reply to a seemingly casual question. One must be like a lawyer examining a witness. Yet Indians become restive and irritated if they feel that they are being questioned too closely. In my own work, I try to have the Indian feel that we are friends, talking over things in which we are mutually interested. In that way he becomes interested in clearing up points that I do not understand, and in the end I have the desired information.

A reservation is like any small community, and each man is known to his neighbors. On one of my first visits to the Red Lake Reserva-

tion in Minnesota I recorded songs from a strange Chippewa who said that he was a good singer. My interpreter was absent at the time and the man seemed so sure of himself that I made no inquiries about him. The records of his songs contained no sense of a keynote and were melodies on which strange theories of primitive scales might have been based. When my interpreter returned I told him of this recording and he exclaimed, "You didn't take songs from *that* man! He can't carry a tune. Let me hear the records." He was able to recognize the songs and offered to record them. In his rendition they became simple little melodies with tones clearly referable to a keynote. As I became more experienced, I would decline to take songs from such a singer after hearing his first recording. Unlike white musicians, Indian singers are not sensitive, and a man is not offended if I say, "Your voice is not good enough for me to record." He is probably disappointed because he is not able to earn money, but he shows no resentment.

Personal character as well as musical ability is taken into consideration in the selection of singers. For this information I depend upon the interpreter and consult the white people at the agency. During the work among the Sioux a singer was brought by an informant, and data concerning the Sun Dance was recorded. Robert Higheagle was absent and another interpreter was obtained. When Higheagle returned, a few days later, he said, "There is trouble among the Indians. John Grass and other prominent men say they will have nothing more to do with the work if So-and-so is connected with it. He killed a man, and his record in other matters is not good." The matter was carefully considered and the responsibility placed on the man who introduced him. Finally his material was expunged and I never saw him again.

A good voice is not essential when the old songs are being recorded. Many old men and women who know the best songs have weak voices but it is possible, with care, to obtain a record that can be transcribed. Such songs are usually connected with magic power or with the treatment of the sick and were received in dreams by the singer or obtained by him from men who received them in that manner. The procedure is different if dance songs are desired. The dance is attended and the leader at the drum is observed with special care. Later, he or other singers are asked to record songs that were used on that occasion and the descriptions of the songs are aided by hearing them at the dance. My work has included many classes of modern dance and game songs, in all tribes under observation, but the old songs will be first to disappear. Such songs are not taught to the younger generation, who are seldom interested in them. In some instances the old songs are learned by young men but, in my expe-

rience, the rhythms are simplified. Thus I recorded a song from an old man and later allowed a young man to record the same song. In the latter rendition it had become a simple little melody, without the native rhythmic peculiarities. On one reservation a young man from an Indian school told me with pride that he was adapting the old songs and playing them on the cornet. Indian music with the present generation is in a transitional form, and my effort has been to preserve the old songs in their original form.

Women singers are much less in number than men. Women might treat the sick with songs or exercise other power received in dreams, but the number of such women was comparatively small. In some tribes a few women sang around the drum at dances, sitting behind the circle of men and singing an octave higher. The relative number of men and women singers is too large a subject for present consideration, but mention may be made of two classes of Indian songs that are popular. These classes are lullabies and love songs. I once asked an Indian singer about lullabies and he replied, "The women make a noise to put the children to sleep, but it is not singing." Subsequently I obtained two records of a lullaby, from two women. One was little more than crooning and the other was a simple melody, suggesting that the song had gradually taken form from the rather vague "noise to put the children to sleep." As the status of the lullaby is so low in the minds of Indian musicians I leave its recording until near the end of work in a tribe and then obtain one or two records from trusted Indian women. The other subject to be handled discreetly is the love song. This is not a native custom and is usually connected with evil magic or intoxication. Love songs, in the old days, were sung to aid intrigue of various sorts, accompanied in some tribes by the use of figurines or other "charms." A Papago said, "If a man gets to singing love songs we send for a medicine man to make him stop." In all tribes it is said that the love song, in our use of the term, came with the advent of the whites. In one tribe I was warned that if I recorded love songs, the fine old men would have nothing to do with my work. I have, however, recorded both the old songs of love magic and the modern love songs, as they are part of the music of the American Indian. The words of the modern songs generally show a lack of respect for women and boast of fascinations and conquests. I have learned not to ask for their translation in all instances. A prominent Pawnee said, "Songs arising from deep affection and respect were occasionally sung by Indians in the old times, and might be concerning persons who had been married for many years."[2] The cause of the change from these songs of respectful affection to the modern love

[2] Densmore, Frances, Pawnee Music. Bur. Amer. Ethnol. Bull. 93, p. 93, 1929.

song is found in the general change from primitive customs, and began when the young people refused to recognize parental authority in the matter of their affections. The subject of love songs is undertaken only with old, steady Indians.

When the old chiefs were still living, I frequently consulted them in regard to singers. Thus Red Cap, the famous Ute chief, said that he could not sing himself but would delegate his best singers to record the old songs for me. Red Cap stayed in the room while these songs were recorded, and his influence made it possible for me to record songs that otherwise would have perished with the singers. John Grass, the prominent Sioux chief, did not sing but gave important information concerning the Sun Dance and his influence was of great assistance in the work.

A fact to be constantly borne in mind concerning Indian music is that it had a purpose. Songs in the old days were believed to come from a supernatural source and their singing was connected with the exercise of supernatural power. The songs of social dances are a later phase and of less importance. Health, food, and safety were the major concerns of the old Indians, and singing was an important means of assuring these. Ceremonies or ceremonial action was connected chiefly with the first and second of these requisites. The general term "medicine men" is applied to those who were skilled in these important matters, a term not unlike the title of "doctor" in our own race which is applied to others than medical practitioners. I have numbered many Indian medicine men and women among my friends. They have appreciated the value of my work and given their best songs and information, in order that the Indian might be understood more clearly by the white men. Among these interesting medicine men was Sidney Wesley (pl. 3, fig. 1), a Choctaw living near Philadelphia, Miss. His Choctaw name was translated "Kills it himself," meaning that if game had been wounded, or any difficult task was to be performed, he did it himself instead of delegating it to someone else. His long, disarranged hair was said to "show that he is a doctor." Among his songs was one that mentioned hatred of the Folanche and Hispano, and it is interesting to note that contact of the Choctaw with the French ended about 1763 and the contacts with the Spaniards were still earlier. Wesley did not know what the words meant but sang the syllables by rote, as he learned them. He and his friend, Mary Hickman (pl. 3, fig. 2), aided one another in remembering old times, and said they joined in the war dances when they were young. The wars were ended but the dances continued, as in other tribes. The songs were recorded in Mary Hickman's house. Her Choctaw name was translated "Putting it back," and her little house indicated that she was an orderly person.

The most familiar songs connected with the food supply are the Pueblo songs to bring rain. The Chippewa sang to obtain an abundance of maple sugar, and the Plains tribes sang for success in the buffalo hunt. All tribes had songs for success in war, often connected with the use of "charms."

The songs collected in a tribe are a cross section of its culture. Thus the proportion of ceremonial songs recorded is largest in a highly ceremonial tribe, the proportion of healing songs is largest in tribes with rich vegetation and many medicinal herbs, and the proportion of hunting songs is largest in regions where game is abundant. Indian songs are of little value unless correlated with the life of the people. Indian music should be recognized as an important branch of ethnology.

It would be futile to stress quantity in collecting Indian songs, as every good Indian singer knows several hundred songs. Among the Seminole of Florida I recorded more than 200 songs from one singer, without a duplication. This man was Billie Stewart (pl. 4, fig. 1), leader of the Corn Dance in the Cow Creek group. His home (pl. 4, fig. 2) was in the cabbage palm region near Brighton, and his recording was done in two successive seasons—1932 and 1933. Toward the end of the second season he hummed a song of the Quail Dance and said, "I sang that for you last year, so I won't record it again." His wife was a medicine woman known by her maiden name of Susie Tiger, and she recorded several songs that she sang when treating the sick. A marvelous native poetry was contained in the words of these songs.

Other Seminole singers were Charlie Billie (pl. 5, fig. 2), leader of the Corn Dance in the Big Cypress group who recorded the ceremonial songs of that dance, and Josie Billie (pl. 6, fig. 1), who asked that his material be recorded with his Seminole name, meaning Panther. He recorded songs of the Hunting Dance and other valuable old songs. An interesting informant on Seminole customs was Mrs. John Tiger (pl. 5, fig. 1). Several villages in the Everglades were visited and photographed, including a camp known as Old Camp Florida.

TRANSCRIPTION OF RECORDS

The transcribing of records is seldom done in the field, as time is so valuable and facilities are limited. The speed screw of the phonograph is removed when the instrument is shipped, and it is necessary to adjust the speed of the instrument when the songs are transcribed. Without this adjustment the pitch would not be the same in recording and transcribing, and the two performances would not be uniform. The desired speed is 160 revolutions per minute and this could be attained by counting the revolutions of the mandrel,

but I devised a different method. The tone C of a pitch pipe was recorded on a wax cylinder. This is placed on the phonograph and the speed screw adjusted until the tone produced by this record is the same as that of the pitch pipe. The piano used when transcribing is tuned to the same pitch (A–440). Thus the pitch of the singer's voice and the original tempo are preserved, and the transcription is made as nearly as possible from his actual performance. The voices of some men extend down to E below the bass staff, though a majority of the records made by men are within a compass of 10 or 12 tones above A, first space, bass staff. It is not unusual for the voice of an Indian woman to go down to E, third space, bass staff, and very few women have voices that extend above C on the treble staff. The Sioux have voices with a particularly large compass and a Sioux woman recorded a song extending to F, fifth line, treble staff.

The outline of a melody is determined by comparing the tones of the record with those of the piano, but the intervals are usually determined by ear.[3] The intervals with simplest vibration ratios are sung with best intonation, many singers showing an intonation that would be creditable to a member of our own race. Indians differ in this respect, and the personality of the singer is taken into consideration when his songs are transcribed. Thus a peculiarity in a record made by an expert singer is given more attention than a similar peculiarity in the work of a man whose performances are known to vary. If several renditions of a song have been recorded they are studied and compared, the transcription being made from the best and clearest rendition.

The presentation of anything as strange as Indian singing must be in familiar terms if it is to be intelligible. Therefore I have used ordinary musical notation with a few special signs and entrusted the differences from that notation, as well as the mannerisms, to descriptive analyses. In this, as in any study, a great deal depends upon the standpoint of the investigator. What sounds strange to our ears is a song to the Indian, and my work has been from the standpoint of a musician who is approaching the music of an alien race. Bytones and various modes of attacking and releasing a tone are common in Indian singing. Early in my work I made an experiment to determine the importance of these vocal sounds. Placing two phonographs with the horns together I played a typical Sioux record, transferring it from one machine to the other until it had been copied six times. On comparing the seventh recording with the original rendition it was found that the seventh was much softer

[3] A certified test of the author's pitch discrimination was made in 1914 by Prof. Carl E. Seashore, dean of the Graduate College, University of Iowa, Iowa City, Iowa. (See Densmore, Frances, Northern Ute Music. Bur. Amer. Ethnol. Bull. 75, p. 209, 1922.)

and the bytones had been eliminated, leaving a clear, pure tone, with intervals comparable to those of our musical system. It is not required that all the sounds produced by our own singers be shown in the notation of a song, and it seems reasonable to make a similar allowance when expressing the singing of Indians. The alternative is to devise an elaborate graphic system, based upon hearing the records or upon tone-photography. Such a system must of necessity be mastered by those who desire information on the subject. To be accurate with respect to Indian music as a whole, the system should be applied to different renditions of a song by the same singer, and to renditions of the same song by other singers. If carried to a conclusion, such a system would produce a vast amount of data, with small variations which are not essential to the song itself. For these reasons, the graphic presentations in my work are limited to "plots" showing the principal progressions of melodies, in order to compare the structure of various classes of songs,[4] and diagrams which show the results of tabular analyses.[5] These were discontinued when it was believed their purpose had been attained. Occasionally a musician or other person with a keen musical ear has been asked to compare the records of the songs with their transcriptions; they have invariably expressed the opinion that the transcriptions were adequate.

In order to test the pitch discrimination of the Indians, a series of tests was made among the Chippewa, Sioux, Mandan, and Hidatsa Indians, using a set of tuning forks kindly lent for the purpose by Dr. C. E. Seashore. The results were tabulated and submitted for examination to Dr. Seashore who expressed the opinion that "the abilities here shown are about as good as one would find among the average American whites under similar circumstances."

A graphic analysis of one of my records was made by means of phonophotography, showing the possibilities of that method. This analysis was made by Dr. Harold Seashore (1934) in the psychological laboratory at the University of Iowa, Iowa City.[6] In respect to pitch, the graph made from the tone-photograph was substantially the same as the transcription by hearing.

In order to test the accuracy of certain observations concerning the relative rhythms of voice and drum, the phonograph, with a selection of records, was taken in 1918 to the laboratory of Dr. Dayton C. Miller, head of the department of physics, Case School of Applied Science, Cleveland, Ohio. The sound was recorded graphically by

[4] Densmore, Frances, Teton Sioux Music. Bur. Amer. Ethnol. Bull. 61, 1918; Northern Ute Music. Bull. 75, 1922; Mandan and Hidatsa Music. Bull. 80, 1923.

[5] Teton Sioux Music, pp. 40–51, figs. 1–18.

[6] Seashore, Carl E. and Harold, The place of phonophotography in the study of primitive music. Science, vol. 79, No. 2056, pp. 485–487, fig. 1.

the phonodeik, an instrument of Dr. Miller's invention, and an analytical study of the result was made by Dr. Miller, with a comparison of the photographs and the transcriptions of the same songs by hearing. Dr. Miller stated "the close agreement of the two methods hardly justifies the great amount of labor involved in the photographic method. This study was undertaken principally to learn what could be done if it were desirable." [7]

In determining the meter of the songs I use an ordinary Maelzel metronome which was tested at the Bureau of Standards. The metronome is not a precision instrument. The marks on its scale are not near together, and the "bob" is some distance from the scale, but this metronome was found to be reasonably accurate with the bob set at 120, on a level with the eye. This indication is about midlength of the scale. For very slow or rapid songs the instrument is placed in this position and the tempo indicated by the position of the bob. The exact tempo of Indian singing is not important, and this mode of measurement is sufficient, the same metronome and method being used with all the songs.

Having determined the meter of the song, it is necessary to note the accented tones by which the transcription is divided into measures. The use of measures does not imply that the Indian has any knowledge of our musical customs, but it is a convenient form for showing the rhythm of his musical performance. Each accented tone is transcribed as the begining of a measure, regardless of the time intervening between the accents. In some songs the accents are evenly spaced; in others they seem erratic, but on further study they often combine to form a rhythmic pattern. Such a pattern usually comprises several measures and is designated as a rhythmic unit. Sometimes a 5–8 measure is followed by a 3–8 measure. The note values may suggest two measures in 2–4 time, but the accent divides the series as indicated. A measure transcribed in 7–8 time cannot be divided, as there is no secondary accent. Quadruple time rarely occurs, but 2–4 time is common in the songs. The accents in a song do not always correspond to the accents in the words of the song when spoken. The rhythm of the song is the rhythm of the melody in the mind of the singer.

The tempo sometimes changes during a song. Such a change may be either abrupt or gradual, and in the latter instance the new time indication is shown when the new tempo is established, preceded by "ritard" or "accelerando." A question to be determined is whether the change is intentional. The several renditions are compared, and, as a general rule, the change is found in all the renditions, showing it to be part of the song. Old Indian singers have a remarkable sense of both pitch and tempo. Thus, Mrs. Holding Eagle, a Mandan, re-

[7] Densmore, Frances, Northern Ute Music. Bur. Amer. Ethnol. Bull. 61, Appendix, pp. 206–210, pls. 12–15, figs. 20, 21, 1918.

corded certain songs in 1912, and in 1916 recorded the same songs again, the pitch and tempo being the same. Other instances of exact duplication have been noted in other tribes, and series of songs recorded by one singer are generally identical in tempo and pitch.

INSTRUMENTAL MUSIC

Instrumental music is used only as an accompaniment to singing among the Indians, except that the young men sometimes play a flute in the evenings and a whistle may be blown in ceremonies or in the treatment of the sick. The musical instruments are of four classes, consisting of drums (or similar percussion instruments), rattles, flutes, and whistles. There are many forms within each class, and the instruments are generally made of materials available in the region where the Indians live. An exception is the gourd rattle, which is widely distributed. Specimens of the musical instruments in the several regions have been collected and placed in the United States National Museum.

Drums of the familiar type are made by tribes that hunt the deer or can obtain deerhide from their neighbors. The Papago, who are not hunters, use a bowl-shaped basket similar to the family bread basket, inverting it on the ground and striking it with the palm of the hand. The Makah, near Cape Flattery in Washington, formerly used a long box for a drum, several men sitting on it and kicking it with their heels or pounding it with their fists in time with the singing. This could be heard in the long wooden houses where their gatherings were held in winter. The same tribe pounded on a plank, when a gathering was held on the shore during the summer. The Indians of British Columbia beat on a plank as an accompaniment to the songs of the Slahal game, the plank being raised a few inches above the ground to produce resonance. The clapping of hands or stamping of feet sometimes accompanied Indian singing, showing the use of the human body in place of an instrument.

Rattles are a form of percussion instrument and may consist of receptacles containing small stones or clay pellets that make a noise when shaken together, or they may consist of objects suspended so that they clash against one another when the rattle is shaken by the hand. Such rattles made of turtle shells or cocoons are sometimes attached to the knee of a dancer and the sound is produced by the motion of his dancing. The gourd rattle is a familiar example of the first type of rattle and an interesting example of the second is a rattle obtained from a Makah medicine man which consists of pecten shells suspended from a hoop of whalebone. The rattle is often connected with magic, and the form of a man's rattle may be in accordance with instructions received in the dream by which he obtained his power.

Indian flutes are of the type known to musicians as the recorder, or flûte à bec,[8] which was the European flute of the Middle Ages. It was held in a vertical position and blown at the end, the instrument preceding the transverse flute of the present day. The recorder is played by blowing into an air chamber at the upper end of a tube, the sound being produced by a whistle opening similar to that of an organ pipe.[9] The typical Indian flute is made of any soft wood with a straight grain, and the number of finger holes varies in different tribes. Flutes are made of cane in tribes that lack suitable wood, and in modern times a gun barrel or piece of metal pipe is used in making a flute. The only transverse flute that I have collected is a cane flute obtained among the Yuma.[10] The playing of many flutes has been recorded and transcribed in notation. In some tribes it is said that certain songs may either be sung or played on the flute, and the Menominee said that love songs were imitations of flute melodies.[11] Several legends of the origin of the flute have been obtained, one of the most interesting being that of the Papago.[12]

The whistle is a simple form of the flûte à bec. Among the Indians it is generally made of the wing bone of a bird and connected with a ceremony or with the exercise of magic power. Such whistles and the wooden whistles are usually short. Certain Plains tribes, however, used a "grass dance whistle" made of wood and about 25 inches in length. This was described by the Sioux and a specimen obtained from an Hidatsa named Pan on the Fort Berthold Reservation. He recorded a performance on the instrument, part of which was transcribed. A portion of the long harmonic series was produced on this whistle, and it is possible that Indians using such a whistle may have obtained a perception of overtones from the instrument.

Robert Henry (pl. 6, fig. 2) is one of the Choctaw medicine men who blow whistles the night before and during a ball game. Each group of players is assisted by the blowing of such whistles. Henry had three whistles, differently marked. The illustration shows a whistle with a crude face, said to be his personal mark.

SCOPE OF THE WORK

The scope of the work has been broad. It was my plan to select representative tribes in each of the large areas, and songs have been recorded from the following:

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[8] Handbook of the Collection of Musical Instruments in the United States National Museum, U. S. Nat. Mus. Bull. 136, pp. 25–27, 1927.

[9] Densmore, Frances, Chippewa Customs. Bur. Amer. Ethnol. Bull. 86, pp. 167, 168, 1929.

[10] Densmore, Frances, Yuman and Yaqui Music. Bur. Amer. Ethnol. Bull. 110, pp. 25, 26, 1932.

[11] Densmore, Frances, Menominee Music. Bur. Amer. Ethnol. Bull. 102, p. 208, 1932.

[12] Densmore, Frances, Papago Music. Bur. Amer. Ethnol. Bull. 90, pp. 54–77, 1929.

Northeastern Woodlands	Chippewa, Menominee, Iroquois.
Southeast (Gulf of Mexico)	Alabama (Texas), Choctaw (Mississippi), Seminole (Florida).
Northern Plains	Sioux, Winnebago, Mandan, Hidatsa.[13]
High Plateau	Northern Ute.
Southern Plains	Pawnee, Omaha, Cheyenne, Arapaho.[14]
Southwest: Pueblo	Acoma, Isleta, Cochiti, Zuñi, Hopi, Santo Domingo.[15]
Southwest: Rancheria and Nomad	Papago, Yuma, Cocopa, Yaqui, Navaho.[16]
British Columbia Plateau	Salish, including Nitinat, and Thompson River.
Northwest Coast	Makah, Clayoquot, Quileute, Tsimshian.
Northern California	Valley Maidu.
Panama	Tule Indians of San Blas.[17]

The Chitimacha Indians in Louisiana were visited but the only surviving members of the tribe did not know any songs. Interesting information concerning the music was obtained, also legends in which songs were formerly introduced.

The Iroquois records comprise a series of ceremonial songs of the Condoling and Installation Council of the League of the Iroquois, recorded by the late J. N. B. Hewitt. These include the Farewell Chant of the Dead Chief, sung by the people as representing the dead chief, the Eulogy of the Founders of the League, and an interesting song entitled "Over the Great Forest."

The songs of Indians in Alaska comprise eight songs obtained at Anvik, Alaska, by the late Rev. John Chapman. They were recorded by dictaphone and the cylinder was obtained by Dr. Aleš Hrdlička, who presented it to the Bureau of American Ethnology. Information concerning the songs was obtained by correspondence with Mr. Chapman, and the record was transcribed in its entirety.

In the collection of records transferred to the Bureau of American Ethnology 27 tribes or large tribal groups are represented by 11 to 356 songs, and 12 small groups are represented by less than 11 songs. Many of the latter songs were recorded by Indians who are not members of those groups. Indians often learn songs from other tribes and sing them in dances and games. No attempt has been made to obtain any considerable number of such borrowed songs.

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[13] The first field trip to the Mandan and Hidatsa was under the auspices of the North Dakota Historical Society. A subsequent trip and publication of results was under the Bureau of American Ethnology.

[14] Field trips to the Cheyenne, Arapaho, and Valley Maidu, and the recording of songs of Santo Domingo Pueblo by a member of the tribe temporarily in Los Angeles, were under the auspices of the Southwest Museum, Los Angeles, Calif. With the exception of the music of the Maidu the results of these trips have been published by the Southwest Museum. A manuscript on the music of the Maidu awaits publication by that museum.

[15] Songs of Acoma, Isleta, Cochiti, Zuñi, Hopi, and Santo Domingo Pueblos have been recorded by singers from those pueblos temporarily in a low altitude.

[16] Obtained from Navaho temporarily in a low altitude.

[17] Songs of the Tule Indians were recorded by Indians from that locality, temporarily in Washington, D. C.

The following list shows only a portion of the work, as many hundreds of songs have been recorded and not transcribed. The summary comprises work from September 1907 to November 30, 1941.

1. Transcribed records submitted to the Bureau of American Ethnology and transferred in 1940 to the National Archives for permanent preservation	2,237
2. Transcribed records submitted to the Bureau after the collection was transferred to the Archives	150
3. Transcribed records in possession of Southwest Museum, Los Angeles (copies of 33 of these included in item 1)	205
4. Transcribed records in possession of North Dakota Historical Society	40
Total	2,632

CONCLUSION

The two principal observations made by those who have listened to the singing of Indians are that it is chiefly rhythmic and that it is minor in character. The rhythm of Indian singing appears first because of its prominence and insistence. The songs heard by a casual observer are generally the songs of dances, but a study of the recorded melodies shows that the rhythm of important Indian songs is more elaborate than the rhythm of corresponding songs in our own race. A desire to check these and other impressions prompted my analysis of recorded Indian songs. It was not difficult to assign a keynote to most of the melodies by the test of the ear, and the songs were divided into two groups, major and minor, according to the interval of the third and sixth tones above this apparent keynote. The term "key" was avoided and the term "tonality" decided upon, partly at the suggestion of Charles K. Wead, examiner, United States Patent Office, about 1909. It was found that more than three-fifths of 180 Chippewa songs under analysis were major in tonality. In subsequent analyses of larger groups of songs it was found that the minor third was the most frequent interval except the whole tone, which is generally a passing tone. The prominence of this interval had given the impression that the songs were minor in tonality, according to our musical system. Continuing this investigation, all the intervals in large groups of songs were expressed in terms of a semitone, and the average progression was found to contain approximately a tone and a half which is a minor third. This table of analysis was last used in my "Yuman and Yaqui Music" (Bur. Amer. Ethnol. Bull. 110, table 13, p. 34, 1932) which shows that the average interval in a cumulative analysis of 1,343 songs contains 3.03 semitones.

The first tabulated analyses used in my work were nine in number, contained in my first book, "Chippewa Music" (Bur. Amer. Ethnol.

Bull. 45, 1910). The melodic analyses comprised such bases as tonality, first progression (upward and downward), and tone material, while the rhythmic analyses noted the beginning on the accented or unaccented portion of the measure and a comparison of the metric unit of voice and drum. The familiar major and minor pentatonic scales were designated as the fourth and second five-toned scales according to the classification by Helmholtz. The various classes of songs were grouped together, making it possible to compare the structure of war, game, and other songs. To Dr. Aleš Hrdlička, curator of physical anthropology, United States National Museum, I owe the suggestion that the results be expressed in percentages, a custom begun in 1913 and followed in subsequent work.

The number of tables of analysis was increased to 22 in my second book, "Chippewa Music II" (Bur. Amer. Ethnol. Bull. 53, 1913), and this number was gradually reduced until only 14 were used in "Nootka and Quileute Music" (Bur. Amer. Ethnol. Bull. 124, 1939). When the results of an analysis were practically uniform in the tribes under consideration the basis was discontinued, and certain other tables did not seem of sufficient importance to be continued. Among those used for only a few hundred songs were tables showing the metronome time of the voice and drum, and the keynote of the song. These analyses were regarded as tests, and no claim was made that they were scientific; neither was any claim made that the results would apply to all songs of all Indian tribes. They were concrete observations on the material under consideration, which represented as nearly as possible the music of certain tribes of Indians.

As a preliminary to the tabular analyses, each song was analyzed, using forms devised and printed for that purpose. In recent years I have continued the individual analyses and combined the results in descriptive groups or tribal analyses. A comparison of the songs under consideration with songs previously analyzed was used for the last time in "Nootka and Quileute Music," in which 210 songs of that group were compared with 1,343 songs of other tribes. The discrepancy between the tribal group and the total number of songs had become so great that a comparison was scarcely justified.

Mention may here be made of a group of songs designated in the analyses as irregular in tonality and comprising songs without an apparent keynote. This designation was adopted at the suggestion of Charles K. Wead, who suggested that the material could thus be reserved for future consideration. The designation was used first in "Teton Sioux Music" (Bur. Amer. Ethnol. Bull. 61, 1918) and has been continued in later work. The table concerning the tone material of the songs contains a group designated as "other combinations of tones."

Some of these songs contain only three or four tones, and others are wandering melodies, according to the present basis of classification.

Throughout this study the objective has been to record the structure of the Indian songs under observation, with my interpretation. Other students, scanning the material, may reach other conclusions. My work has been to preserve the past, record observations in the present, and open the way for the work of others in the future.



ŚIYA' KA, SIOUX SINGER.



HENRY THUNDER, WINNEBAGO, RECORDING SONGS IN A GROVE.



1 SIDNEY WESLEY CHOCTAW MEDICINE MAN.



2 MARY HICKMAN, CHOCTAW INFORMANT



1. BILLIE STEWART, SEMINOLE, LEADER OF THE CORN DANCE IN COW CREEK GROUP



2. BILLIE STEWART'S CAMP, IN CABBAGE PALM REGION.



1 MRS JOHN TIGER, SEMINOLE INFORMANT



2. CHARLIE BILLIE, SEMINOLE, LEADER OF THE CORN DANCE IN BIG CYPRESS GROUP.



1 PANTHER (JOSIE BILLIE), PROMINENT SEMINOLE SINGER.



2. ROBERT HENRY, CHOCTAW, BLOWING WHISTLE USED FOR SUCCESS IN BALL GAME

SNAKE BITES AND THE HOPI SNAKE DANCE

By M. W. STIRLING

Chief, Bureau of American Ethnology
Smithsonian Institution

[With 1 plate]

The most widely known American Indian ceremonial is undoubtedly the so-called Snake Dance of the Hopi Indians of Arizona. Actually the Snake Dance is only the concluding feature of the elaborate 9-day Snake Ceremonial, which is held in alternate years at most of the Hopi pueblos primarily as a prayer for rain. During the preliminary days of the ceremony live snakes, including both venomous and nonvenomous varieties, are ritualistically gathered from the vicinity of the pueblo and brought to the kiva. Here they are utilized in the ceremonies, preparatory to fulfilling their role as messengers upon being released on the final day when the public ceremony is held, during which live snakes held in the mouth are danced with.

Because of the peculiar attitude of the typical white man toward snakes, once the Hopi ceremony became publicized it aroused unusual interest, with the result that an enormous literature on the subject has been published since the first description appeared in print in 1881. Some of the early scientific investigators had unusual opportunities of observing the ceremonial in fairly complete form, so that a number of excellent descriptions were written before the tourist influx made the Hopi more secretive toward the whites. It is not the purpose of this paper to discuss the ritual or its esoteric significance. For the benefit of the interested reader a selected bibliography is attached. The intent of this article is merely to put in condensed form the answer, at least in part, to one of the most frequent queries received by the Bureau of American Ethnology, namely, "Are the snake dancers ever fatally bitten; and if not, why not?" (For a detailed and excellent treatment of this matter see Klauber, 1932.) The complete answer to this query is fairly complicated and is largely bound up in the fact that the average white man is highly superstitious regarding snakes, and the Indian is not.

Likewise the typical white man is even more ignorant regarding the habits and actions of snakes than he is of most other animals, since his superstitions cause him to avoid them. The Indian, on the other hand, is a realist regarding snakes and is as well versed in snakelore as in any other native form of life.

The only venomous snake available to the Hopi is the prairie rattler, *Crotalus confluentus confluentus*. A study of the results of 128 bites by this species revealed 8 fatalities (Hutchison, 1930). Some of these had the benefit of antivenin treatment, so that a true fatality percentage might be somewhat higher. Therefore the prairie rattler may be considered a moderately dangerous snake. Many factors, of course, affect the seriousness of the bite. Among these might be mentioned the size and health of the victim, the location of the bite, and the amount of venom injected. Thus we might assume that an adult dancer struck fairly by a rattler with full poison glands would suffer painful though probably not serious aftereffects. A small boy participant, on the other hand, struck in this manner, would probably suffer serious results, possibly fatal. A number of instances of dancers being bitten by rattlers, including some of small boys, have been recorded in the literature by reputable observers. In no case, however, have uncomfortable results been reported nor have the recipients of the bites retired from the ceremony after being bitten. In short, it is evident that the Hopi snake dancers do occasionally get bitten by venomous snakes. Since they are reasonably cautious and skillful in the handling of the rattlesnakes, such bites are not very frequent. From reports of competent observers and from the Indians themselves it would appear that serious results never follow, even though small-boy initiates are sometimes struck. The reason for this seeming immunity has been speculated upon at great length by observers of widely varying ability. Klauber has listed some of the more common theories which he has summarized in three groupings, as follows:

A—CONDITIONS AFFECTING THE AUDIENCE

1. The audience is suffering from some form of group hypnotism.
2. The audience is not qualified to distinguish venomous from nonvenomous species.

B—CONDITIONS AFFECTING THE SNAKE PRIESTS

1. The priests have taken an internal protective medicine prior to the dance.
2. They possess knowledge of antidotes—internal, external, or both—which, taken after an accident, quickly render rattlesnake bite innocuous and even painless.
3. Sucking, cauterizing, and arresting the circulation by tourniquets are resorted to in case of accident.
4. The priests are so purified by the ceremonial emetic as to be immune.
5. They are smeared with a preparation so disagreeable to the snakes (as, for instance, in odor) that the latter will not bite.

6. They are covered with an invulnerable preparation, as, for instance, a thick paint.
7. They are so healthy from outdoor life that rattlesnake bite does not affect them.
8. They have an immunity resulting from a long fast prior to the dance.
9. They build up an immunity by increasing doses of venom, as is done with horses in the preparation of antivenin.
10. They have a mysterious hypnotic power over the snakes, akin to that said to be possessed by the snake charmers of India.
11. They are fearless of snakes, which, therefore, are without power to bite them.
12. They are protected by the religious exaltation of the ritual.
13. They are actually bitten with serious results, of which outsiders are kept in ignorance.

C—CONDITIONS AFFECTING THE RATTLESNAKES

1. The snakes' fangs, venom glands, or both have been removed.
2. Their mouths have been sewed closed.
3. They have expended their venom on harmless snakes or other objects in the kiva.
4. They have been milked of their venom in the kiva.
5. They are tame snakes used repeatedly in successive years.
6. They have been lately tamed by handling.
7. They are doped or hypnotized.
8. They are starved into submission.
9. They are blinded by the sacred meal, or paralyzed by the tobacco fumes from the ceremonial smokes in the kiva.
10. August is the blind season for rattlers; they cannot see to strike.
11. They are invariably held in such a way that they cannot bite.
12. The eagle feather snake-wands prevent their biting.
13. They cannot strike because they are not permitted to coil.
14. Rattlers are relatively innocuous anyway.

Most of these theories obviously do not hold; others, deserving of consideration, can be proved false. That venomous snakes are actually danced with is, of course, amply demonstrated. It is also true that a portion of the ceremony involves the taking of an internal "medicine." This, however, is "magical" in nature and not concerned with the matter of snake bites. After being bitten in the dance, the Hopi also take an "antidote" prepared from herbs, as do almost all Indians when bitten by snakes. This "antidote" has been subjected to careful scientific tests, however, and found to be completely ineffective (Coleman, 1928). The Indians, of course, do not claim this medicine to have a physiological effect, but regard it as a protective charm, since their ideas of the cause of the disagreeable results of snake bite are quite different from ours (Mindeleff, 1886a). The emetic taken by the Hopi after the dance for purposes of purification also quite obviously could have no effect on a poison which affects the blood stream.

The fact that the snakes have been kept captive for several days preceding the Snake Dance, during which time they are handled, un-

doubtedly takes considerable edge from their aggressiveness, as it is a commonplace observation of zoo keepers and others that rattlesnakes in captivity tend quickly to lose much of their fear of those handling them.

The theory has been frequently advanced that the fangs of the snakes have been removed when they are captured, or later in the kiva. Curtis (1922) states that one of the priests told him that the fangs of the snakes are pinched off with the thumbnail when caught. Other later writers have claimed to have recaptured released snakes and found their fangs removed. It is probable that in recent years, as a result of acculturation, some of the Hopi villages have adopted this precaution. However, it is quite certain that originally this practice was never followed, as too many careful students of the Snake Dance have specifically testified to the contrary. Klauber, an expert herpetologist, saw at close range rattlers expose their fangs during the dance at Mishongnovi. Lummis reports a rattler hanging by its fangs from the cheek of a dancer. Scientists have occasionally recaptured rattlesnakes immediately after the dance and found the fangs intact. In 1883, Dr. H. C. Yarrow, a competent herpetologist, was admitted to the kiva before the dance and examined one of the rattlers, finding its fangs intact. After the dance, two rattlesnakes were sent to Washington and found not to have been tampered with (Mindeleff, 1886b).

Since rattlesnakes are accustomed to strike from the coiled position, they would doubtless be in a somewhat unfavorable position as carried in the mouths of the dancers. Nevertheless there is ample evidence that they can and do sometimes strike under these circumstances.

After carefully analyzing all the evidence, Klauber advances the conjecture that the principal reason for the lack of serious results from bites received in the Snake Dance is that the poison glands of the rattlers are previously emptied, either by allowing the snakes to strike some soft objects or by the simple process of "milking" the glands. Klauber says:

> If I were an Indian engaged in this dance I would not be satisfied to take a chance on the admitted and known docility of the rattlers, especially having in mind the danger to some of the boys of 8 years, or even less, who, as novitiate priests, take part in the ceremony. Without taking any step which would injure the snakes (even temporarily, as by the removal of the replaceable fangs), I would use the simplest, least apparent, and safest method of rendering the snakes almost innocuous, that is, by thoroughly emptying the venom glands. This statement is based on a personal experience in the milking of well over 2,500 rattlesnakes.

To summarize briefly, the popular appeal of the Snake Dance is the result of the white man's peculiar attitude toward snakes. The average person has an exaggerated idea as to the potency of rattlesnake venom. With moderate-sized rattlers, such as the species

used in the Snake Dance, a bite with full poison glands should result fatally in less than 1 out of 10, in the case of adults.

Owing to knowledge of the habits of the rattlesnakes, previous manipulation and confinement of the snakes, skill in handling, and teamwork in the dance, the Hopi dancers are not frequently bitten. However, occasional bites do occur but apparently never with serious results. The principal reason for this is probably that during previous handling the poison glands of the snakes have been emptied or the venom considerably reduced in quantity.

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SNAKE CEREMONY IN PLAZA AT MISHONGNOVI, AUGUST 1901.

At the left a dancer, escorted by the "hugger" with feather wand, carries a snake in his mouth. At the right stands a "gatherer" with feather wand and holding snakes in his hand
Photograph by Matteson.

THE ESKIMO CHILD

By Aleš Hrdlička

Curator, Division of Physical Anthropology, U. S. National Museum

[With 10 plates]

There is no more pleasing or richer study in the field of physical anthropology than that of the human child; and a study of the Eskimo young is in some respects even more remunerative than that of the white because the subject is less familiar, and because the surviving Eskimo child is usually healthy, normal, and brought up without modern artificialities.

The Eskimo mother and father, though less demonstrative, love their children at least as much as do the average mother and father of our race. The Eskimo mother, in fact, sacrifices herself even more for her babies than does the average white mother of our time. Her children are more dependent on her, as under the hard conditions of life in the North the father is of even less help than in our civilization, and she wants to give them the best she has in every particular. On the other hand, the Eskimo child, as long as it is healthy, is a very contented little creature, giving but little trouble.

The Eskimo woman as a rule loves to have as many children as she can, and in every Eskimo community there are plenty of them; but until recently many died from digestive disorders, exposure, and infections brought in by whites. Various travelers and casual observers, seeing the frequently small Eskimo families, drew the conclusion that the Eskimo woman was not prolific. This, actual observations and records have shown, was erroneous. There are, of course, women among the Eskimo, as there are among all peoples, who for some reason bear but a few children, and, rarely, even no child at all; but those are exceptions. The true conditions may be seen from the records of the last United States censuses and from those taken by special observers. I have given the available data in one of my papers.[1] According to the 1930 census[2] relating to the Alaskan Es-

[1] Fecundity of Eskimo women. Amer. Journ. Phys. Anthrop., vol. 22, p. 91 et seq., 1936.

[2] See also Anderson, H. C., and Eell, W. C., The Alaska natives: A survey of their sociological and educational status, pp. 138–139. Stanford Univ. Press, 1935.

kimo, "the live birth rate per 1,000 of the Eskimo population in 1928 was 47.1 as based on returns from 12 representative villages. The birth rate per 1,000 in the registration area in the United States for the same year was 19.7."

One of the regions in which there are large numbers of pure-blood Eskimo in good condition is that of the Kuskokwim River and the neighboring area. Here live about 4,000 of these people, partly civilized, partly still following the old Eskimo ways. In this region an investigation on 27 full-blood Eskimo women at the end of the childbearing age showed that the average number of children born alive per woman was 6.2; or, eliminating two women who bore but two children each, 6.6. Among the American Indians the number of children borne by women during their childbearing period averages about 7.

There is, therefore, no dearth of babies among the Eskimo. As a matter of fact, since receiving more effective medical assistance the people are increasing in numbers, notwithstanding the periodic deadly epidemics of influenza, frequent tuberculosis, and other diseases of white man's introduction.

In rare instances an Eskimo woman will give birth to twins. At present such children would probably be brought up, but in the more strenuous past such an occurrence might have meant too much of a burden, leading to the elimination of the weaker infant. Nothing definite, however, is known on this subject among the Eskimo. The old people would doubtless still remember, and it would be worth while for someone who has their confidence to inquire into the matter. As to triplets or other multiple births, nothing could be learned.

The Eskimo baby comes generally without any expert assistance and, as is usual with people of simple life and good resistance, accidents are uncommon. There are still practiced various old customs relating to both the mother and child which ought to be recorded and published, but the Eskimo have a lot of good common sense and have learned no small amount from both the Russians and the Americans, so that in many details they now behave at birth and thereafter much as would our own poorer people under similar conditions.

The babies as a rule are chubby and, when healthy, more quiet and patient than ours. They look very much like Indian children and, were it not for their more or less brownish color and the fold at the inner corner of each eye (epicanthus), would look but little different from equally chubby white infants. At first they seldom cry, and spend most of their time in sleeping or feeding. They are carried along by the mother wherever she goes, and at home they lie on skins or blankets. They apparently commence to smile, creep, walk, and

talk in the same order and at much the same time as do our children, but on these points precise observations are still needed. When ailing, they are very responsive to cod liver oil and other remedies, as are also their mothers.

There is a general tendency to nurse the baby longer than is the practice among the white people. Formerly, as soon as the baby had some teeth it was given also tidbits of meat and other food, including bought sweets, which often did more harm than good. Feeding practices are now being regulated by instruction in the school, with the advice of the nurse and the physician; and the mothers are very responsive, so that infant mortality is decreasing. There is, however, still much to be done in this direction.

The Eskimo mother usually carries her baby in the hood of her parka, and the tot seems perfectly contented there—it will even sleep there a part of the time. Occasionally, the child is carried on the mother's shoulders, the feet straddling her neck. There are no cradleboards among the Eskimo, and no head deformation, either intentional or accidental. Older girls, as elsewhere, help with the young children.

An "education" or training of the Eskimo child begins early. For a girl it is usually attended to by her mother and grandmother, for a boy, by the father and uncle. The girl is taught the womanly duties and arts, the boy, boating, hunting, and trapping. Strangely, though living by and largely on the water, none of them ever learn to swim—the waters are too cold. Until recently, when customs began to change, the boys grew exceedingly expert with the kayak (a small skin canoe for one person), and later also with the umiak and umiak-pak, the larger skin boats of the people. They learned how to throw a dart, spear, and harpoon—bows and arrows were used much less and only on land; and they learned all the arts, wiles, and lore of the hunter and trapper. There were, of course, differences in the aptness of the pupils or in talents in special directions, and those with outstanding abilities were much honored.

There is but little punishment of the children among the Eskimo. I have witnessed some spankings by the mother—never by the father. The Eskimo children in general give less cause for punishment than ours—they are more orderly, less mischievous. The boys have but little restraint, yet do not seem to abuse their freedom much—for one thing there is not so much chance, and for another there is a group discipline, once adolescence is reached, to which they must conform. In all my contacts with the people I never heard a complaint about the children. One sees them everywhere, and from the age of 3 or 4 they begin to be helpful, doing something useful in connection with

the dogs, wood, or boats; as they grow older and stronger, they help also in the hunt, with the fishing, handling the game, and in other activities.

But the life of the Eskimo child is far from being all serious and all work; there is also much play, and it would be hard to find a happier lot in this respect than theirs. They play in very much the same way as would our children under the same conditions, but there is less altercation and more steadfastness. The girls play with rag dolls, which in some instances are provided by the father or uncle with an ivory or bone head and perhaps even hands and feet; and they build from pieces of driftwood and earth little houses, exactly as would ours. They are happy and talk and laugh and pretend, but are never very loud. Inside they play and help about the fire, or make little odds and ends for their dolls. The boys like boys' play, sport, and contest, but from the beginning their games are related to their future occupations.

Personal embellishment in Eskimo children is now limited to the girls. Formerly, the boy at puberty had a hole made on each side of the lower lip in which he wore for the rest of his life a labret of wood, bone, ivory, lignite, or stone; and there were perhaps other practices, but all that has long since been given up. With the girl decoration begins in infancy. It consists at first of a simple necklace, now generally of varicolored beads, with perhaps a little cross hanging from it. As the girl grows, more strands of beads are added, and bead strings are also intertwined with the hair, producing a pleasing effect. A few now wear also a simple ring, but that has been learned from white people. The young and also older women used to be tattooed and painted themselves for ceremonies, but that too has all been given up. Aside from the beads, the acme of embellishment in the older Eskimo girl is a beautiful white-patched reindeer skin parka (robe), with a gorgeous wolverine hood collar.

The Eskimo children formerly wore charms, and some of these are perhaps still in use, but they are not in evidence; even the children among the Eskimo are sensible people.

The Eskimo children, particularly the girls, love living pets. The most common of these are the fat, shaggy puppies of their dogs. There are no ordinary watch dogs or pet dogs or cats—they would not live long near the jealous and powerful sled dogs. Some of these latter, more particularly the mahlemute breed, grow large, strong, and fierce. A visitor dares not approach them; yet a 4- or 5-year-old Eskimo boy with a stick will fearlessly walk among them and even hit them, without any of them resenting it. But should a child fall down within their reach, as happens now and then, they will pounce upon it and kill it, should no help come—the old wolf habit. The young, however, make very nice and harmless pets.

There are no social gatherings for the Eskimo children, no communal functions; but they may, it seems, attend the "dances" and singing arranged on occasions by the adults, and also, in summer, any outdoor jollifications.

Thus passes the earlier Eskimo childhood in the Far Northwest. Many interesting local details might still be gathered on this period and should be recorded before it is too late, for the Eskimo is very adaptable and is rapidly changing to a modern way of living and doing things.

With the approach of adolescence the play period of the Eskimo child is largely ended. The boy now is a substantial help to his father, the girl to her mother. The age at which this period begins among the Eskimo girls has within recent years been definitely established in some regions. At Bethel, on the Kuskokwim River, western Alaska, the mean age for 16 full-blood girls was 13.3 years, for 6 mixbloods (Eskimo-White) 13.2 years, with the extremes in the former 12 to 14½ years, in the latter 11 to 15 years.[3] This is much the same as with the majority of healthy white girls (13 to 15 years). In the boys, as with ours, the period is generally a little later.

Formerly, there were among the Eskimo various observances connected with this period, both for boys and girls, but these have now been largely given up. One of the most curious of these practices, which doubtless served as one of the tests and marks of initiation of the youngsters into manhood and womanhood, was the knocking out of one or more of their front teeth.[4] This practice was once widespread over the world, including America, and is still in vogue among the Australians and some other primitive groups. It seems now to be wholly forgotten in Alaska.

During adolescence, many of the young men grow handsome, active, and in cases rather reckless and boastful; the young women often good looking and even very pretty, shy, modest, and in some instances full of inborn naive coquetry, highly enjoyable to the observer. Not a few of these girls now marry local white men, and make them fair wives. The well-trained and educated girls brought up by such establishments as the Moravian Orphanage on the Kuskokwim River are especially sought for, so that there are generally a number of native grooms, with now and then a white, awaiting their release.

The outstanding sports for the Eskimo youth are wrestling and tossing. Wrestling has always been in great repute among the

[3] For details see the writer's "Puberty in Eskimo Girls." Proc. Nat. Acad. Sci., vol. 22, pp. 355–357, 1936.

[4] See the writer's "Ritual Ablation of Front Teeth in Siberia and America," Smithsonian Misc. Coll., vol. 99, No. 3, 1940.

Alaskan Eskimo. Matches, the old-timers say, were held yearly between the Eskimo of northeastern Siberia and those of St. Lawrence Island and the Kotzebue region. To this day, high on the hill at Gamble (St. Lawrence Island), the Eskimo show burial places of famed wrestlers.

The tossing game was probably brought over by the Russians. It consists of a girl or a boy, standing on a skin held outstretched slackly some feet above the ground by strong young men, being tossed up by a combined jerk that straightens the skin, dropping down, being tossed up higher, and so on until the players tire. I have seen a young woman thus tossed up, as high as 5 feet above the skin, rising and descending time and again, as straight and stiff as a doll. It is no mean sport and must call for no small ability on the part of both the tossed and the tossers.

A healthy Eskimo child is a happy and lovable creature and, except for less boisterousness, nervousness, and self-consciousness, is very much like our own average youngster. They are tractable, malleable, and, though less demonstrative than ours, become genuinely attached to a good teacher. They are by no means stupid or stolid, and as soon as the difficulties with language are overcome, they progress very much as do white children. When the girls marry, if fate gives them good husbands and spares them illness, they keep their homes as clean and bright as could any of their white sisters.

When a child dies there is deep though undemonstrative mourning. A small, sickly infant is not mourned for so much, but the loss of a larger or stronger child is felt deeply. It will never be voluntarily spoken of, and its name will never be mentioned. The loss is particularly felt when no more children can be had by the mother, and may then be compensated for more or less by the adoption of an orphan.

The Eskimo population as a whole is happy, resourceful, and virile, and everyone who truly knows them must wish them all possible good. May we be wise and just enough to save their children from the many unnecessary deaths, and aid in every rational way to restore and further develop this excellent strain of native people, who are utterly American, and may yet be the saving element for many parts of Alaska.



1. ESKIMO CHILDREN.
The "Little Mother," Seward Peninsula.



2. ESKIMO MOTHER AND CHILD, NOME REGION.



1 ESKIMO MOTHER AND HER TWO CHILDREN, SEWARD PENINSULA.



2. ESKIMO CHILD, NORTHERN BERING SEA.



1. THREE ESKIMO BOYS, QUISHLOK, MIDDLE KUSKOKWIM.



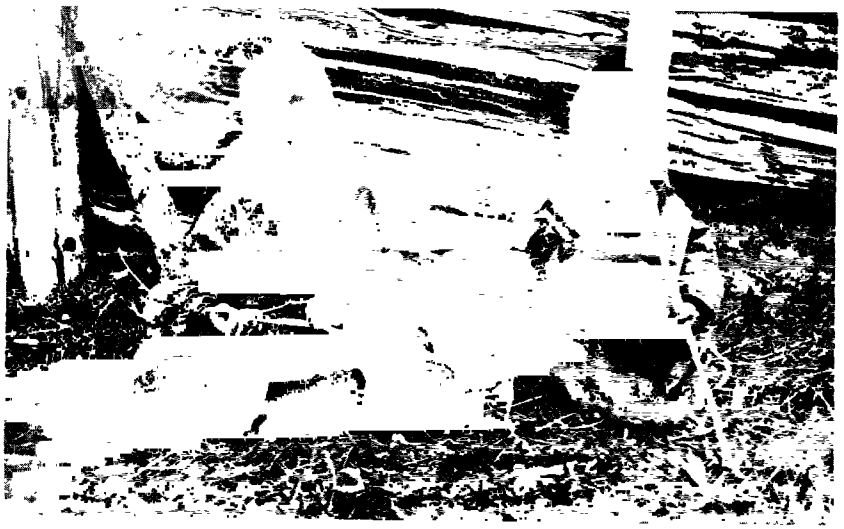
2. THREE LITTLE ESKIMO GIRLS, QUISHLOK, MIDDLE KUSKOKWIM.



1. ESKIMO CHILD, MORAVIAN ORPHANAGE ABOVE BETHEL



2 ESKIMO CHILD KUSKOKWIM.



1 ESKIMO BOYS, SOUTHWESTERN ALASKA.



2. ESKIMO CHILDREN, BETHEL.



ESKIMO TEACHER'S FAMILY, ON LITTLE DIOMEDE.



1 ESKIMO GIRL, MORAVIAN ORPHANAGE ABOVE BETHYL.



2. ESKIMO GIRL, KUSKOKWIM.



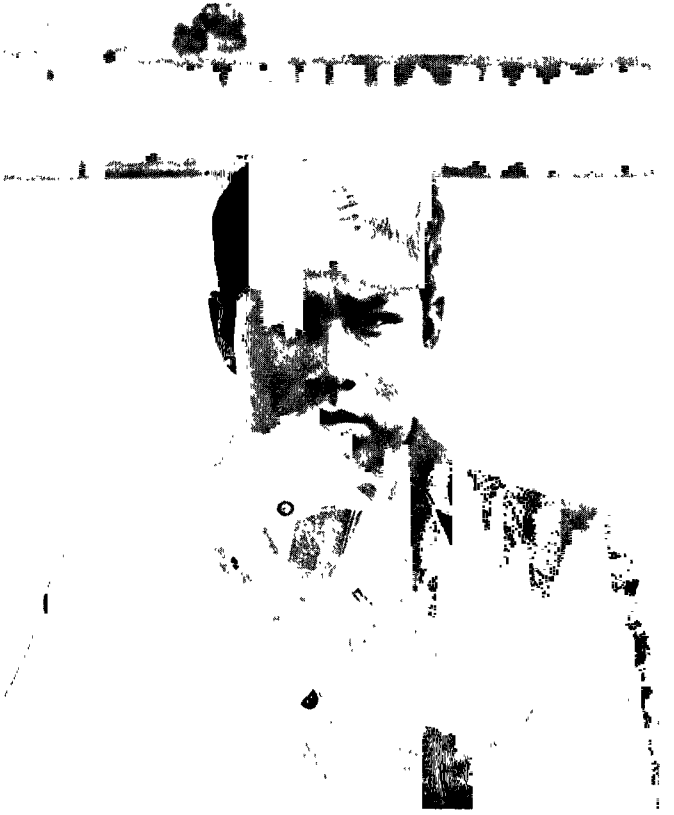
1. FULLBLOOD ESKIMO BOYS, WALES



2 ESKIMOS AT MOOSE CREEK CAMP, UPPER MIDDLE KUSKOKWIM



1 AN ADOLESCENT ESKIMO GIRL, WALES



2 AN ADOLESCENT ESKIMO BOY, ST. LAWRENCE ISLAND.





ADOLESCENT ESKIMO GIRL, ST. LAWRENCE ISLAND.

WINGS FOR TRANSPORTATION[1] (RECENT DEVELOPMENTS IN AIR TRANSPORTATION EQUIPMENT)

By THEODORE P. WRIGHT, D. Sc.

Vice President and Director of Engineering, Curtiss-Wright Corp.

[With 14 plates]

During the past few years, we have been forced to think of the airplane's future more in terms of "air power" than "air transport." Starting with Munich, air power assumed a dominant role in international affairs. It is fortunate that we, in this country, have been able to maintain a better balance between military and commercial aviation so that we can continue to appreciate that the ultimate role of the airplane is to serve peaceful purposes.

It is not intended to imply that we can, for an instant, relax our efforts in building up our air force; we cannot play the role of the lamb in a world of wolves. But in spite of this necessity for military aviation to receive such great attention, it is still essential to look into the future and study the possibilities and objectives of air transportation. This is important now and will be more so after the present conflict is ended.

TRANSPORTATION

"The very pace of life depends upon the speed with which matter can be converted into energy available for transportation." Let us consider transportation in general: the carrying of goods or persons from one place to another. We constantly seek to reduce the effective size of the earth and to increase the effective span of human life. Progress in this field has been marked by a succession of improvements paralleling the development of civilization itself: First by walking, "leg power"; then by domesticated animals; by the invention of the wheel; by the application of steam and the internal combustion engine to the railroad and the automobile and the steamboat; and now finally by the airplane. In each case, ourselves or our goods move from where

[1] Presented at a joint meeting of The Franklin Institute and the Philadelphia Chapter of the Institute of Aeronautical Sciences held Wednesday, December 6, 1939. Reprinted by permission from the Journal of the Franklin Institute, vol. 229, No. 4, April 1940.

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they are to somewhere else that we want them to be in some amount of time. It is significant that the quotient of distance over time is velocity, or speed.

What then differentiates this latest means of transportation from the others? It is true that it strikes off into a different medium, one of three dimensions, the air, but the essential difference is that it carries out the function of transportation at greater speeds. From moving under his own power at 4 miles an hour, man has contrived to increase his speed to 40 miles an hour by automobile, to 65 miles an hour by rail, to 200 miles an hour by air when traveling long distances. One may ask: Is it likely that air transportation will continue to advance and augment its services, even to become the major means of transportation? To do this it must be economically sound; and the year just ended shows that progress has reached a stage of advance where this is now the case.

We wish to see where we are going in this new field. Trends are therefore important, and it is a major object of this paper to discuss this item of trends, alluding to some of the engineering methods that have been used in order to reach our present status, and to others which will be used in order further to improve. Finally, we ask: Should it be? Is it in general good for man to be able to travel from place to place three or four times as rapidly as was heretofore possible? Will his life be fuller and richer and will there be greater happiness for a greater number if this maintains? My answer to all of these questions is "Yes," as in the final analysis, the destiny of the airplane will be to serve peaceful rather than warlike purposes. But the attainment of such objective will not be automatic. We cannot be too certain. We must constantly bear in mind the social implications of science, and make sure that civilization is advanced and not retarded by our scientific progress, particularly by its most recent acquisition, the airplane.

HISTORY

With this brief statement of the case, let us now examine more particularly the history of air transportation. In a lecture given by Mr. E. P. Warner at Norwich University on this subject, he selects as a starting point the year 1870 and I will follow his example.

The Franco-Prussian War was under way and the city of Paris was being besieged. Normal communication with the outside provinces was completely cut off. The Parisians finally resorted to the use of the free balloon to remedy this situation. During the 127 days of siege, 64 balloons were sent up from Paris, carrying some 4 million letters and 88 passengers to the outside world. Only a few of the balloons were lost, either at sea or to the enemy, so that this initial effort in air transportation may be considered to have been successful.

This means could be used, of course, only for transportation out of Paris, but an ingenious method was devised for making possible the dispatch of return communications. Each balloon carried a quota of homing pigeons when it left Paris which were subsequently released with reply messages.

The next step in aerial transportation took place in 1911, also using lighter-than-air craft. A service utilizing 5 Zeppelins was operated for 2 years between several cities in Germany. During this time, over 34,000 passengers were carried, traveling 107,000 miles in all with no loss of life. The service was far from satisfactory economically and was abandoned.

But we are interested primarily in heavier-than-air craft. The epoch-making flight of the Wright Brothers in 1903 was followed by 9 or 10 years of activity which involved flying, but not air transportation. Aviation meets consisting of much stunt and demonstration flying were the rule.

Almost from the first, however, the prospect of carrying mail by air was in the minds of all these enthusiasts though it was not until the end of this period of infancy that any official carriage of mail by air took place. Preceded by stunt mail-carrying wherein a small amount of mail might be transported to a flying field by auto truck, flown about a bit, perhaps to another field, and then picked up by another (or possibly the same) truck and carried back to the same post office, a real start was made on September 23, 1911, when the Post Office Department authorized Earle Ovington to make an official mail flight. Emphasis must here be placed on the fact that at that time it was the carrying of mail that appealed to the popular fancy as the goal of the airplane.

Several isolated attempts at starting air transport lines took place following this period, such as one in 1914 which operated with a single flying boat between St. Petersburg and Tampa, in Florida, a distance of 36 miles. All of these efforts, essentially uneconomical, were abandoned after short periods of operation. Greater airplane efficiency had to be realized before success could be attained.

A real start, however, was made in 1918 when the Post Office Department decided to fly the mail between New York and Washington, D. C. The Army Air Service, with Maj. Reuben Fleet in charge of the operation, was designated to do the job since initial bids for airplanes designed especially for the service resulted in delivery dates for the craft which were unsatisfactory to the impatient officials. The first flight was made on May 15, 1918, and was intended to consist of a trip in each direction. The flight of the plane leaving Washington, with the take-off witnessed by the President of the United States and members of his Cabinet, terminated shortly thereafter in southern

Maryland, completely off the course. The trip from New York, however, was successful, consuming 3⅓ hours' time at a cost, in this Army training plane, of approximately the same amount per mile as is now required to fly a modern 14-passenger transport with many times the load and speed. However, the line continued and great credit is due this pioneering effort to carry the mail regularly by air, a service which has never ceased to improve and expand.

Landmarks in this expansion followed in rapid succession. One was the opening of the New York-to-Chicago route in 1919, using rebuilt wartime DH–4 airplanes. Another, and an illuminating vision of the future, was the first crossing of the Atlantic Ocean by air—the successful undertaking of the United States Navy, using NC–4 flying boat.

On September 8, 1920, the first transcontinental flight was made during a competition, one plane getting through in 9 days 4½ hours. But an event of outstanding importance occurred on February 22, 1921, when Jack Knight completed a night flight from Omaha to Chicago, under terrifically unfavorable weather conditions. His way was lighted only by occasional bonfires. Lighting of this sort at frequent intervals had been promised but because of weather conditions so unfavorable to flying, many communities failed to light their fires. Made possible by this night flight, mail was carried from San Francisco to New York in about 33½ hours, approximately twice the time now required for a similar service.

Another important event of 1921 was the inauguration by the Army Air Service of a regular Dayton-to-Columbus airway for night flying. Here the revolving beacon with periodic flashes was developed, an innovation which was to prove so advantageous in the system of airways later evolved for this country. Its inherent advantages over the simple lighthouse type favored in Europe contributed much toward the more rapid advance of air transportation in this country. The lighted airway from Cheyenne-to-Chicago was completed and put into operation on July 1, 1921. This was a most important step in progress as by it a great number of enthusiasts of that time appreciated anew the fact that in order to take full advantage of the airplane as a means of transportation night flying must be used. This country surpassed Europe by a wide margin both in the proportion and technique of night-flying operations.

By 1927, the Post Office Department had satisfactorily established its basic air-mail system and was ready to turn it over to private operators. The last flight by the Department was on September 1, 1927. It had expended 17 million dollars in its pioneering efforts, had received back about 7 million and thus gave to the American people a magnificent start in air transportation at the exceedingly

small relative net cost to the taxpayers of 10 million dollars. The operation had been dangerous and had resulted in many fatalities, as must all pioneering efforts, but the fatality rate decreased sharply from its inception to the final flight at which time it was at least 10 times as safely conducted as at first.

Having outlined the progress in carrying the mail which was the first use to which the airplane was put in commerce, let us now consider the progress in carrying passengers. As remarked above, at first passenger-carrying did not strike the American public fancy as the final role of air transport. This differed from the attitude in Europe where passenger-carrying rather than mail-carrying seemed to be the goal, and consequently where the start in air transportation was made. However, there were a few lines in the United States, the primary purpose of which was to carry passengers. These were started in 1919 and operated between New York and Atlantic City; Miami and Nassau; Seattle and Victoria, and Key West and Havana. It is noteworthy that they all used flying boats and that although some useful service was given, they were not by any means successful financially.

In 1920, the Army Air Service again made a distinct contribution when it inaugurated its model airways system. Capt. Burdette S. Wright initially supervised the operation which lasted through the next 5 years, involving a total of 336,000 miles of flying. Aside from the contribution made in requirements of cross-country flying for Army officers, a real lasting service was provided air transportation by spreading air-mindedness to hundreds of communities along the airways. This resulted in a period of airport development of great importance.

The relationship between Government and private enterprise in developing air transport was very unsatisfactory at this time. Recognizing this, a group known as the Morrow Board was appointed by the President to investigate the situation. A very statesmanlike report was made, resulting in the passage of the Air Commerce Act on May 20, 1926, a date to be noted as an important landmark in air transportation development in this country. An Assistant Secretary of Commerce for Air was appointed and steps were taken for regulating air transportation for the future. Then, in 1927, came the solo trans-Atlantic flight of Colonel Lindbergh which set the country aflame with enthusiasm for the air. Expansion followed at once with such lines as National Air Transport, Transcontinental Air Transport, the Aviation Corporation network (later American Airways), United Aircraft and Transportation Corporation, and Western Air Express, organized and started in operations by 1929.

Another development of far-reaching significance was the inaugu-

ration of the Pan American Airways System which started in 1927 with a run of 90 miles from Key West to Havana. This line expanded rapidly to 12,000 miles in 1928, encircling the Carribean, and then to South America in 1930, further extending its mileage to 30,000. We all know and are proud of the more recent developments of Pan American Airways wherein the Pacific was spanned in 1935, bringing the total mileage to 33,000, and the Atlantic in 1938, raising the figure to 54,000 miles, a truly remarkable development and one envied by all the countries of the world. Pan American has furnished a most important service to our country in extending communication services to the far-flung points on its routes. In the future, this dual role, transportation and communications, will be important in international affairs.

But to return to a somewhat earlier period, we find that by 1931 there had been completed the phase of mergers which sought to combine the great number of individual air-line companies previously organized into basic groups much as we know them today. If aviation's "infancy" ended in 1911, we can say that its "childhood" ended in 1926 and its "adolescence" in 1931.

One of the first air lines to be formed in Europe was K. L. M. in 1920. Its record of expansion and achievement has made it one of the greatest lines in the world. We, in this country, are rather proud of the fact that the equipment which it has used during the last 5 or 6 years has been of American design and manufacture—Douglas planes with Wright engines. Imperial Airways was formed in 1924, Lufthansa in 1926, and Air France in 1933. Perhaps the most significant difference between foreign air lines and our own is in the matter of subsidies. In the first place, the amount of subsidy abroad was and is larger than ours; and in the second place, the subsidy has usually taken the form of direct payment to the air lines as against the American way of payment for carrying the mails. In addition to the far smaller proportion which the subsidies of our air lines bear to income from other sources than maintains abroad, the method of determining it, as mentioned above, is of equal importance in inducing American air lines to make themselves self-sustaining economically. This is certainly the ultimate goal and its attainment is much more nearly approximated here than abroad. It is so much the case that many doubt the correctness of calling air-mail payments here a subsidy as they seem really to represent a legitimate Government expense in providing a most necessary service.

This very brief history of air transportation can be concluded by stating that after 1931, which ended the period I called "adolescence," wherein its own development was its chief concern, the industry started its next period of "young manhood." Its strength was by

then such that from the standpoint of competition it could force consideration on other forms of transportation. Let us therefore consider the broad relationship between air transportation and transportation by rail.

AIR TRANSPORT IN COMPETITION WITH OTHER TRANSPORT METHODS

In table 1 this comparison shows that by virtue of greater speed and shorter distances, the time-saving factor favors the air by about 3½ to 1. The fare differential favors travel by rail by a ratio of 3 to 2, but combining the two in a time-cost efficiency factor, there appears a resultant gain for the air by 2½ to 1. A more refined analysis is given later but because of the existence of these broad considerations, the rapid expansion of air transport has resulted. Let us now view this progress in terms of equipment.

TABLE 1.—*Transportation: rail vs. air*

	Variation	*Average*
Speed between stations over 200 miles apart	0.30 to 0.40 : 1	0.33 : 1
Distance between stations over 200 miles apart	1.05 to 1.22 : 1	1.15 : 1
Time between stations over 200 miles apart	3.00 to 3.90 : 1	3.50 : 1
Fare[1] between stations over 200 miles apart	0.65 to 0.70 : 1	0.66 : 1
Time-cost efficiency factor=1/cost factor × time factor	0.30 to 0.49 : 1	0.434 : 1

[1] Fares cited are based on quotations for 1-way trips, including Pullman fares in the case of rail travel, and not taking account of reductions for round trips, for use of scrip tickets or excursion rates, or other special considerations, such as the saving in expense for meals when traveling by air. The result of combining such factors will react to the advantage of air travelers, giving, in round numbers, a time-cost efficiency factor favorable to the air when comparing to rail of about 2.5 : 1.

EQUIPMENT USED IN AIR TRANSPORTATION

Starting from the use of Army training planes during World War I and later modified Army observation planes, it was not until 1926 that types designed specifically for air-transport use appeared. As an example of this early effort, plate 1, figure 1, illustrates the Boeing Model 40, a biplane designed much along the Army observation plane formula but nevertheless specifically built for air transport. Its cruising speed was about 100 miles an hour. By 1929 the Ford trimotor had come into use for air transportation at a cruising speed of about 105 miles an hour (pl. 1, fig. 2). The expansion of the air lines at this time and the period immediately following was very largely based on the Ford, which appealed to the popular fancy because of its monoplane arrangement, its all-metal construction, and its three engines. Not economical to operate in the light of present standards, it nevertheless seemed to operators of those days the last word in efficiency and many considered that nothing

better need be expected. It was noisy, it was none too comfortable, but, after a fashion, it did the job.

The Curtiss Condor (pl. 1, fig. 3) appeared in 1930. Although a biplane in accord with the earlier traditions, it nevertheless marked a distinct advance in two respects. First, it had two engines and would actually fly at a reasonable altitude in a satisfactory manner when one engine was inoperative. Secondly, it made a very distinct contribution toward comfort for passengers, both from the standpoint of the luxurious seats which it provided and, more particularly, because of the installation of sound-deadening means which reduced the cabin noise level to a point approximating that of other means of transportation. It had a cruising speed of 116 miles an hour.

In Europe at about this time there appeared the Handley-Page Hannibal (pl. 2, fig. 1), a biplane type equipped with four engines but cruising at under 100 miles an hour. A fair degree of comfort was provided but its slow cruising speed would not seem to justify the long period of service that it had on Imperial Airways.

A sesquiplane, the French Breguet Model 39, was developed in 1934, and the German Junkers triplane came out that same year. Like the Ford, this latter was all-metal construction and had three engines, but, unlike the Ford, it had a low-wing rather than high-wing arrangement.

In this country, the next plane which should have special mention was the Boeing 247 (pl. 2, fig. 2), also appearing in 1934. Cruising speeds were raised to 180 miles per hour by this ship which also had most of the present-day features of form, including all-metal low-wing twin-engine monoplane construction with retractable landing gear. This type is still giving good service on several air lines. In 1934, there also appeared another version of the Curtiss Condor, the chief contribution of which was the introduction of the sleeper arrangement for night flying. Plate 2, figure 3, illustrates the interior of this ship alternatively arranged for use during the day and at night. With planes of this type American Airlines started its popular cross-country sleeper schedules.

As to flying boats: a step ahead occurred when the Sikorsky S–42 was placed in service on Pan American Airways. Although the first large boat used by that company was the Consolidated Commodore, nevertheless, the S–42 and S–42A were and still are standard equipment for the South American runs. Plate 3, figure 1, shows this Sikorsky.

It was also in 1934 that the Douglas DC–2 appeared, embodying all the essential improvements which are used in the present-day air transport. In addition to the use of two-engine, low-wing all-metal monoplane arrangement with retractable landing gear, introduced by Boe-

ing, it also incorporated the Wright Cyclone engine with NACA cowl, the wing flap with resultant permissible increase in wing loading, and the controllable-pitch propeller. Cruising at 180 miles an hour with a complement of 14 passengers, it provided a degree of excellence in air transportation unequaled (if not indeed unapproached) by any other piece of equipment. It is indeed fitting that the Guggenheim Medal should be awarded to Donald Douglas this year in recognition of his contributions to air transportation, starting as he did mainly with the introduction of the DC–2. Plate 3, figure 2, is a view of this airplane in flight.

Again to revert to flying boats, there is shown in plate 4, figure 1, the Martin 130, by means of which the Pacific route of Pan American Airways was opened up. Cruising at 130 miles an hour, this flying boat possessed a very high ratio of useful load in proportion to gross weight.

The next big step in equipment development was the Douglas DC–3, the present standard of air-transport equipment of the air lines of the world. Although developed directly from the DC–2, nevertheless, by virtue of greater span and larger fuselage, coupled with slightly more power permitting a substantial increase in useful load, it has made possible very great economy of operation. With a gross weight of about 24,000 pounds and a payload of 5,000, it cruises at 181 miles an hour and can be operated at a direct operating cost of $65 an hour; 39 cents a mile; and 1.8 cents per 200-pound payload unit per mile. This airplane is shown in plate 4, figure 2.

TRENDS

Having illustrated the advance in air-transport equipment to this point, it is desirable now to show by a series of graphs the trends which are indicated for various phases of our subject.

GROWTH OF AIR TRANSPORTATION

First, let us consider the growth of air transportation as illustrated in figure 1. The four sets of curves are self-explanatory in showing a tendency to accelerate in growth during the past 2 or 3 years, and particularly in 1939, as measured by growth in airways, passengers, passenger-miles, and ton-miles of mail and express. One can only reach the conclusion from these data that there will be a substantial period of time before any falling off in tendency to increase may be expected.

ECONOMIC ASPECTS

Now let us consider certain economic aspects of the situation in a second group of graphs (fig. 2). Here, under figure 2 (*A*) is indicated the saving involved by air travel as against rail when considering

all factors of expense, including salary loss, and under three classifications. For the middle case, a salary of $3,500 per year, it appears to be economical to travel by air if the distance involved is 750 miles or greater, and under the assumption that the alternative of rail travel would be carried out at night to cut down the salary loss while traveling to nothing or to a minimum. If travel were to be carried out in the daytime by either means of transportation, the lines representing air and rail travel cross at about 200 miles for all salary brackets.

Under figure 2 (*B*) a few statistics are shown. Reduction in passenger fare from 12 cents a mile to 5.7 cents has brought this item to a point where, from figure 2 (*A*), it appears reasonable travel economy is effected. The tendency for passenger-load factor to stabilize at 60 percent requires some comment as, offhand, it might be considered that a larger amount would be necessary or at least desirable. However, it should be realized that in order to attain this average, there must, of necessity, be many trips which are 100 percent filled. It is also evident that at 100 percent load factor, it would be likely that in many cases passengers would be turned away because of lack of capacity. Furthermore, such a lack of capacity would imply failure on the part of the operators to render a service which can reasonably be expected by the public. It appears that the tendency to stabilize at 60 percent will persist and that air lines must therefore reckon on making their operations satisfactory to themselves financially on this basis.

The next noteworthy item is average trip length which is apparently stabilizing at about 400 miles, a decrease from a few years ago due to a tendency recently for short-haul traffic to increase. Next, there is the figure of 95 percent efficiency in completing trips started.

In figure 2 (*C*) there is shown the increase in air traffic against Pullman traffic from a figure of just over 3 percent in 1935 to almost 7 percent at the present time (December 1939). As the points on which this curve are based lie on a straight line, it is reasonable to expect continuation of this tendency, reaching 10 percent by 1945. It is possible that there will be an acceleration thereafter and several have prognosticated a final flattening out at 40 or 50 percent. Apropos of this possibility should be mentioned the comparison of bus and rail traffic. A comparison of these two modes of travel showed that but 1 percent as many people traveled by bus as by rail in 1920 while by 1932 a figure of 37 percent was reached.

Trans-Atlantic air travel has only just commenced, but in view of the loads now being carried by Pan American Clippers, it can confidently be predicted that the proportion of air to first-class boat travelers will be substantial. The market is available, as recent anal-

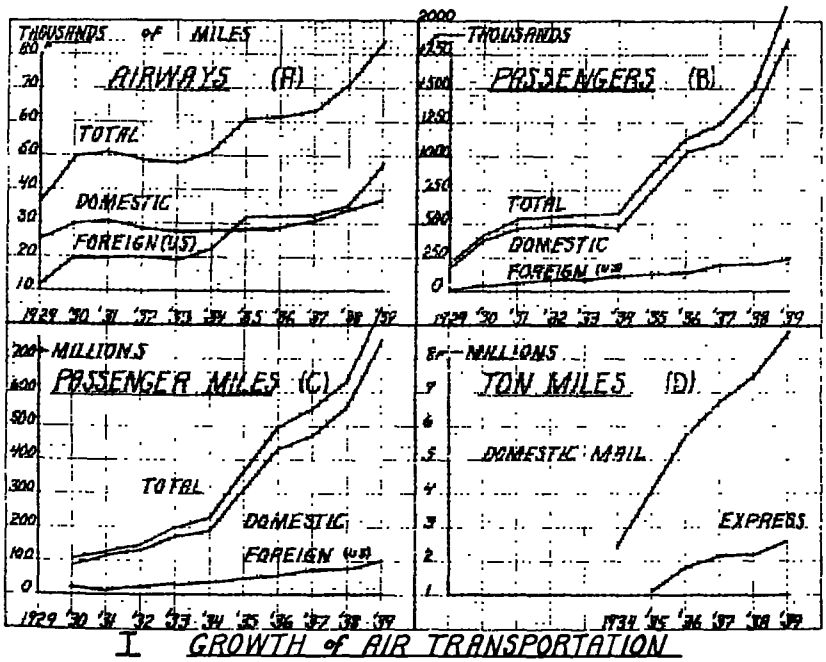


FIGURE 1.

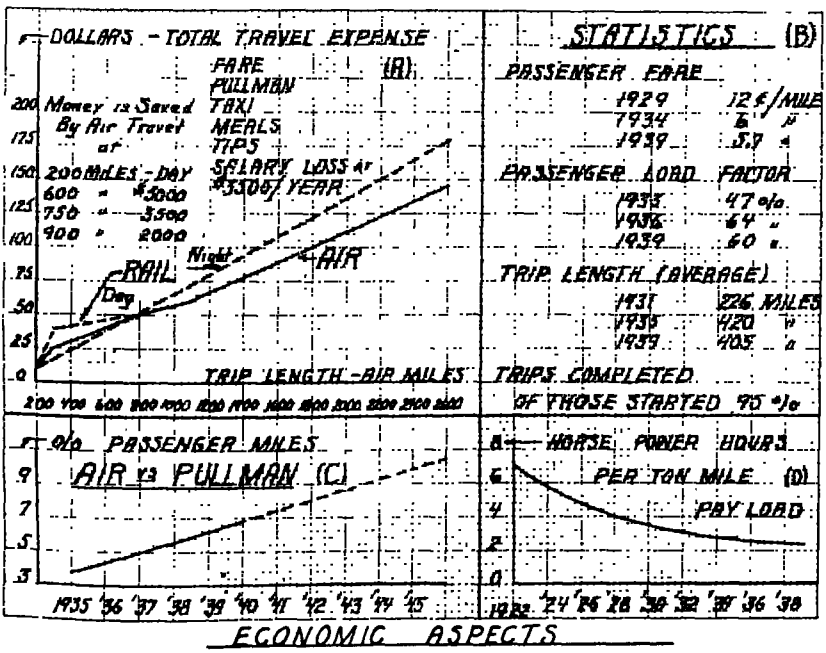


FIGURE 2.

yses have shown that in normal times there are a hundred or more passengers per day crossing the ocean in liners and who pay rates comparable to those asked by Pan American for air passage. Already Pan American, with over 100 crossings to its credit, is averaging about 20 passengers a trip on a twice-a-week schedule with occasional schedules of 30 or 40. Mail, averaging about 1 ton a flight, has occasionally gone to 3,500 or 4,000 pounds. It is rumored that more frequent schedules will be justified in the near future in the expectation that even in peacetime such frequency of schedule will be justified.

The last subdivision of figure 2, graph (*D*), shows the improved efficiency of the airplane as measured in terms of horsepower-hours per ton-mile pay load. This factor has decreased (showing increased efficiency) since the start in 1922 from a figure of seven to a present figure of just over two. The fact that this curve has flattened out is a clear indication that the difficulties of further improvement will be great. It should be noted, however, that in general our air lines made a profit in 1939. I previously mentioned a direct operating cost of 1.8 cents per passenger-mile for the Douglas DC–3 airplane. If a 66 percent overhead is assumed and a 60 percent capacity load factor, it means there is an actual operating cost of 5 cents per passenger-mile. Subtracted from present fare averages of 5.7, a profit of 0.7 cents per passenger-mile, or just over 12 percent, results; so passenger air transportation with present equipment can be made profitable.

GROWTH IN SIZE

The graphs of figure 3 are designed to illustrate the growth of the airplane itself. It should be realized that average curves have been drawn to show the tendency to increase in size. Naturally, there are smaller pieces of equipment coexistent with larger. In fact, curves (*A*), (*B*), (*C*) of figure 3, rather than being averages of all equipment, are more accurately a trend of the largest sizes for any given period. The tendency of the weight curve, (*A*), for landplanes to flatten out as against the nonexistence of any such tendency for flying boats is significant in connection with the different type of service each provide. The long-distance service of the flying boat requires less frequency of schedule and makes it likely (as indicated in graph (*A*) of fig. 3) that greater and greater sizes will be developed. However, for landplanes, the desire for a service "every hour on the hour" automatically sets a limit on size increase. It is perhaps noteworthy that the Douglas DC–4 airplane which will first be placed in service is not the original DC–4 but a smaller version. This flattening out in size curve for landplanes will, of course, not persist if in the future, as may well occur, landplanes are used for transoceanic service.

Graphs (*B*) and (*C*) of figure 3 show, respectively, increases in horsepower and cost of equipment. Twin-engined landplanes costing $115,000 may be expected to increase to over $225,000 and four-engined equipment in the $350,000 bracket will be with us soon. In the flying-boat field, we are now in the half-million-dollar class. Graph (*D*) of figure 3 shows the steady increase in average seating capacity, rising from 7 in 1932 to 14 at the present time.

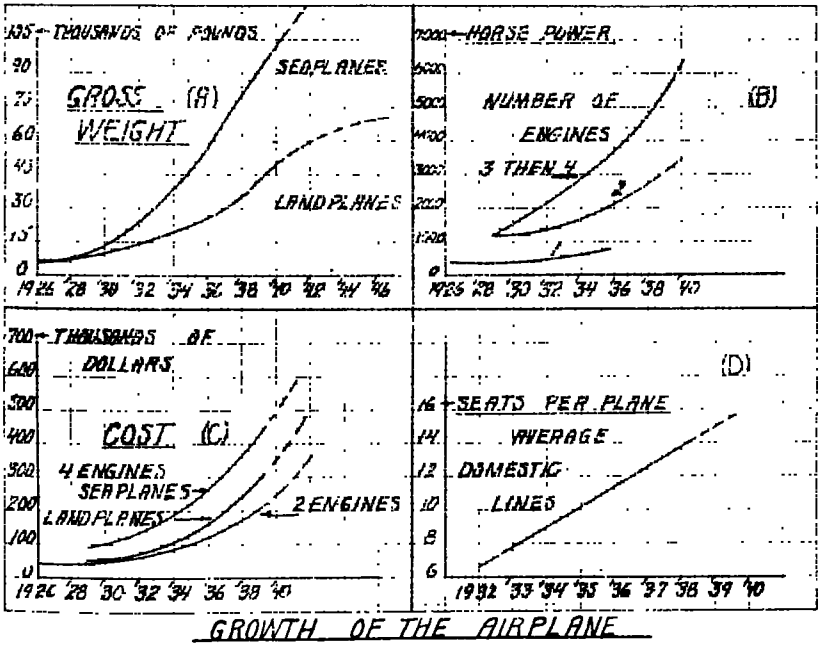


FIGURE 3.

COMFORT AND SAFETY

The curves of figure 4 are presented to show improvements in comfort and safety.[2] Graph (*A*) is extremely important, in that the steady increase in weight per passenger of passenger furnishings and safety equipment shown has been so marked in the past 10 years that we have arrived at the point where the operator now carries the equivalent weight of two passengers and baggage for every one that he actually carries! In other words, passenger furnishings now amount in weight to 175 pounds per passenger with safety equipment at about 15 pounds. This increase of 150 pounds per passenger of such equipment between the old Ford and the Douglas DC–3 is a good measure of the improvement in comfort of the modern air liner. An interesting side

[2] I am indebted to E. T. Allen for the data necessary to plot curves (*A*) and (*B*) and in one or two of the other curves shown.

comment here concerns the fact that because of the increase just described, it has not been possible to increase the useful load in terms of percentages of gross load. In fact, an actual decrease has occurred. From 1929 to 1939, this percentage has decreased from 40 to 33, where it appears to be stabilized. For flying boats, during the same period, it started at 45 percent and increased in certain instances to 50 but now seems to be stabilizing at 42. The fact that it has not gone down still further is only due to improvements in structural efficiency which have been accomplished.

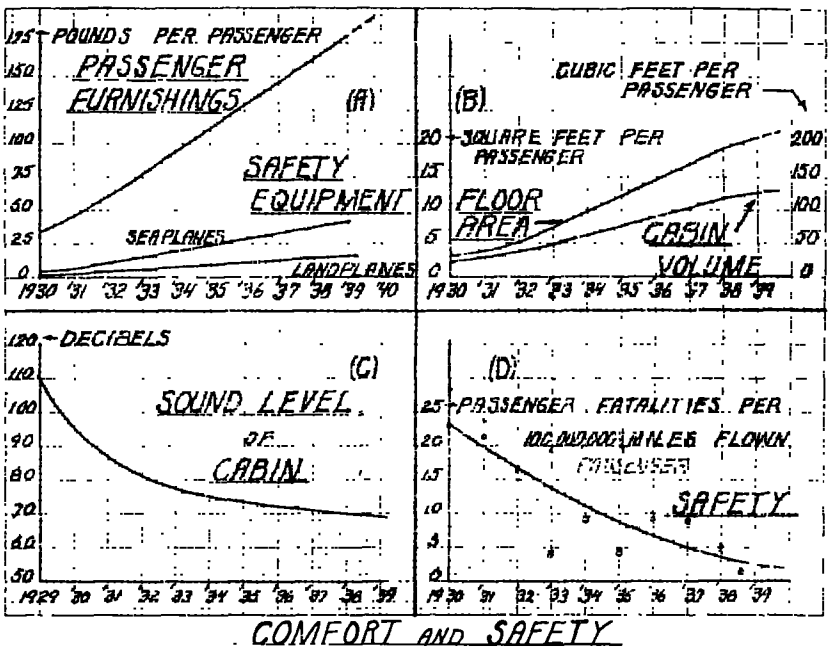


FIGURE 4.

Provision for increased space as shown in figure 4 (*B*) will be recognized at once as a substantial contribution toward passenger comfort. These curves for flying boats give values roughly twice those that maintain for landplanes. For the latter our modern transport planes provide over 10 square feet and 60 cubic feet per passenger. But from the standpoint of comfort, it is perhaps figure 4 (*C*) which shows the most important contribution, namely, reduction of noise. The decibel unit (old scale) is used and it may be seen that from the days of the Ford in which noise of 110 decibels existed, we are now in the 70-decibel range. This 40-percent decrease is (as mentioned above) based on the decibel unit which, in turn, is a logarithmic scale measurement. The actual sound in our present-day air-transport cabins is

but 1/50,000 as much as 10 years ago. In fact, it is almost exactly the same as for the Pullman car, being, of course, far less than in streetcars and subway trains, and only slightly more than for an automobile traveling at 50 miles an hour. To obtain further improvement will require expenditure of a greater amount of weight, and it is likely that a final stabilizing figure of 65, or possibly slightly less, will maintain.

And now for safety (fig. 4 (*D*)). Here have been shown the actual points for each year which have maintained during the past 10 years for passenger fatalities per one hundred million passenger-miles flown and a trend curve. The record is remarkable and important. Let us take the year 1938, where the figure is five, and let us appreciate that this figure represents one fatality for twenty million passenger-miles, which is the equivalent of a flight each day from New York to Los Angeles and back the next day, carried on without interruption for 21 years. The record for 1939 is very substantially better (an actual figure of less than 1¼), so much so that President Roosevelt issued a special news release on this record on November 7, 1939, by which date 500 million passenger-miles of air-transport operations had been completed without a fatality and which, as he dramatically pointed out, was the equivalent of transporting the whole population of the city of Washington to Boston and back. This record has continued unblemished, approaching two-thirds of a billion passenger-miles now, and unstinted credit is due air-line operators for the infinite number of details earnestly carried out which brought about this fine condition.

Substantial contributions have also been made by our plane and engine designers in the airplane itself to help make this record possible. A few of these are: The use of multi-engined equipment having satisfactory flying qualities under all conditions of flight; the general improvement in stability and controllability; the improvement in reliability of the power plant; the perfecting of the constant speed propeller; tremendous developments in instrumentation; the use of de-icing equipment; and the current efforts to reduce or eliminate pilot fatigue by making the pilot's job easier and his working conditions more comfortable. The important advances in the field of meteorology, radio communication, and airway traffic control should also be stressed.

AIRPLANE CHARACTERISTICS

The final curves, figure 5, illustrate trends of airplane characteristics. Cruising speed, in 10 years, has roughly increased from 100 to 200 miles an hour—(*A*). A rather slight flattening-out tendency is now evident although there will be a substantial lapse of time before the limit for certain classes of equipment is reached. In the graph of figure 5 (*B*) are plotted the trends of wing and power loadings. Noteworthy is the flattening-out of the wing-loading trend

curve for landplanes at a figure of just under 35 pounds per square foot. It is likely that seaplane loading will continue upward although both may be further increased (than shown by these curves) as the result of introduction of assisted take-off means. Power loadings have not decreased greatly and will probably stabilize at about their present figure.

In connection with landing speeds, figure 5 (*C*), the flattening-out tendency of the curve is indicated, but it should be mentioned that in general it can be shown that for equal safety, landing speeds can legitimately increase proportionately to the sixth root of the gross weight. Here again, therefore, the curve depicts the trend for the largest sizes of equipment and it may be expected that for smaller planes the landing speed will be less.

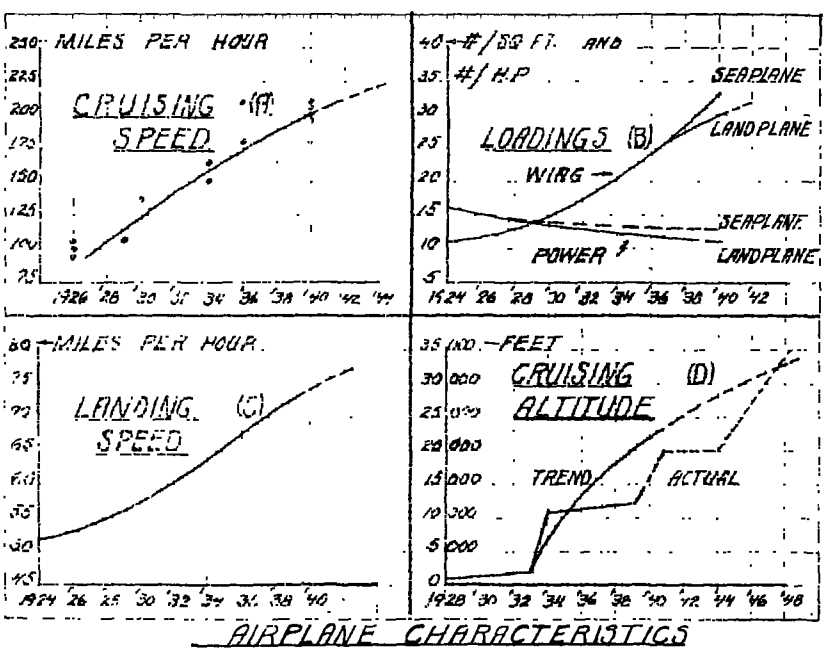


FIGURE 5.

Next we consider cruising altitude, graph (*D*) of figure 5, where the jumps represent for the most part changes in the power plant which permitted economical flight at successively higher altitudes. Starting from just over sea level, there was a jump in the DC–2 airplane to cruising at approximately 10,000 feet which remained the case until the present time, December 1939. Equipment just about to make its appearance will raise this to 20,000 feet and it is my belief that eventually 35,000 feet will be utilized for certain classes of equipment and service.

MODERN AIR-TRANSPORT PLANES

These curves, then, show the trend. Let us now see some of the most modern air-transport planes now operating or about to be placed in service. To start off again at the point where we previously stopped—the Douglas DC–3 airplane—let us note in plate 5, figure 1, the interior of this ship as used by United Airlines between New York and Chicago. The picture speaks for itself as to the provisions which are made for passenger comfort. Plate 5, figure 2, shows the interior of a DC–3 accommodating 21 passengers as used on most of the air lines in this country and many abroad.

In plate 6, figure 1, is a view of the Short Empire flying boat which is a thoroughly modern piece of equipment used by Imperial Airways and seen in this country on its trial trans-Atlantic flights and in the New York-to-Bermuda service last year.

Next we see in plate 6, figure 2, the Boeing 314 which has done such yeoman service in Pan American trans-Atlantic operations. Another view, of the interior of this ship, in plate 6, figure 3, gives an idea of the spaciousness and comfort that the passengers enjoy when traveling on these Clippers.

The Lockheed 14 in plate 7, figure 1, although smaller in size than the DC–3, provides a very excellent and comfortable service at the high cruising speed of 220 miles an hour.

Plate 7, figure 2, shows the DC–5, about to be put into feeder-line service in this country. It is noteworthy for the introduction of the tricycle landing gear.

In plate 7, figure 3, there is shown a very fine view of the Boeing 307 Stratoliner, several of which were recently ordered by TWA and Pan American, to be placed in service this year. And in plate 8, figure 1, we have a DC–4, the largest of land air transports yet produced. It is noteworthy, not only for its fine performance and load-carrying ability but again for the introduction of the tricycle landing gear.

THE FUTURE FOR PERFORMANCE

And now to examine three more tables indicating the possibilities of the future for speed and range. In table 2 are shown the factors which made possible the 80 percent increase in cruising speeds which occurred from 1929 to 1939. The preponderant effect of aerodynamic cleanness shown in the first item is noteworthy, with the additional substantial items of increased wing loading, decreased power loading, flying at higher altitudes, and wing efficiency; following with minor improvements in the last three items, induced drag, propeller efficiency, and weight reductions brought about by structural weight improvement. These features have brought the speed from 105 to

430577—42——38

TABLE 2.—*Airplane cruising speeds: factors causing increases of the past 10 years and possibilities of the next 10 Years*

Item	Description of the item in detail and improvements involved	Speed improvement	
		Actual	Possibilities
		1929–39	1939–49
		Percent	*Percent*
"Wasted" drag	Streamline shape; smooth surfaces; interferences; improved nacelles; elimination unnecessarily exposed parts; improved Reynolds Number accompanying size increase.	36	9
Wing loading	Improved flaps and sections	17	4
Power loading	Increased allowable landing speed with size increase; higher take-off powers with improved fuels.	8	0
Altitude flying	Progressively from sea level to 10,000 feet, to 35,000 feet.	9	18
Wing efficiency	By more perfect taper; thinner and improved sections: etc.	7	2
Induced drag	By higher aspect ratios; elliptical wings; etc	1	2
Propeller	Operation at better *V/ND;* blade section improvement.	1	2
Structural	Weight reductions due larger size, better materials, and improved design.	1	3
		80	40
Resultant cruising speeds	Average values typical of the period	*M. p. h.* 105–190	*M. p. h.* 190–266

NOTE.—Further, but more remote possibilities are: Cooling drag reductions or elimination; very high wing loadings using assisted take-off; greater than normal power-plant improvements; complete laminar flow by section change combined with small chord or boundary layer control.

190 miles an hour. My prognostication of increases to 266 miles an hour cruising speeds in the next 10 years will be effected by the same items but with a different relative proportion for each as shown in the second column of table 2. The importance played by flying at still higher altitudes should be noted together with important improvements in drag reduction, although of only one-quarter the magnitude that maintained for the last 10 years. The reason for this is shown in table 3 where it will be observed that horsepower "wasted" in overcoming unnecessary drag is now but 20 percent of the total as against 66 percent 10 years ago. At that time, speeds

TABLE 3.—*10 years advance in aerodynamic cleanness*

Year	Item	
	Wasted horsepower [1]	Actual speed in percent of streamline speed [2]
1929	66	65
1939	20	90

[1] "Wasted horsepower" is horsepower consumed in overcoming the drag of unnecessarily exposed parts or of nonstreamline shapes.

[2] "Streamline speed" is the speed the airplane would make at a given altitude if its only drag were smooth flat plate skin friction; drag caused by efficient cooling of the engine; and induced drag due to lift. Figures are obtained by using the method of B. Melvill Jones.

made good were only 65 percent of what they would have been if all this unnecessary drag were eliminated and a perfect streamline airplane produced. This proportion of actual speed to streamline speed is now 90 percent, leaving only a short way to go in possible improvement.

Table 4 indicates three factors which will contribute toward increasing range by about 30 percent in the next 10 years. It is believed these are self-explanatory. However, it should be noted that

TABLE 4.—*Airplane range: factors causing increase in the next 10 years*

	Percent
Speed increases automatically improve range. The improvement may be of the order of	15
Reduction in *specific fuel consumption*	10
Structural weight reductions	5
Total	30

all of the speed increase shown in table 2 will not go into range increase since that proportion which will be attained by flying at high altitudes will not result in range improvement and, as well, the weight reductions resulting from structural improvements cannot all be used both for speed and range increase. Then too, cruising velocities are higher than schedule speeds which are reduced by time losses in take-off and landing to give what are known as block-to-block speeds. As these losses are constant regardless of cruising speed, the final range increase due to cruising-speed improvement is about 15 percent as shown. A further 10 percent reduction in specific fuel consumption is expected although it will be difficult to obtain when it is realized that in the past 10 years, specific fuel cosumption has dropped from about 0.52 pounds per horsepower hour to about 0.41, a 21 percent improvement.

THE FUTURE OF AIR TRANSPORTATION

Now I shall briefly discuss the future of air transportation. Let us look at plate 8, figure 2, which shows the New North Beach, La Guardia Airport in New York City, from which operations started on December 1, 1939. This magnificent airdrome with its long all-direction runways and fine hangars and waiting rooms, is a definite indication of air transportation's future expansion. Just as those cities which provided themselves with facilities and inducements for the railroads to pass within their limits in the 1870's and '80's, made certain their future as centers of commerce and industry, so likewise the case will be now for those cities that provide themselves with proper airport facilities. At North Beach dual facilities for land and water operations are provided.

Next are shown views of flying equipment which may be important in further development. First, in plate 9, figure 1, there is the Mayo composite airplane arrangement which by means of assisted take-off provides the operating, or top unit, with increased speed and range which may therefore be a factor in trans-Atlantic mail flying.

In plate 9, figure 2, there is shown a view of a model of a helicopter, a type of aircraft which will be used for transporting mail and passengers from airports to roof tops in the centers of cities and even, in many cases, for short-haul traffic directly between city centers. In addition it may revolutionize our conception of private-owner aircraft.

Plate 10, figure 1, is a view of the Curtiss-Wright Model Twenty with pressurized cabin and with extremely large baggage and express compartments. A noteworthy contribution to economy of operation is expected when this plane goes into service, making it eminently suitable for use between large centers of population. Other views of this plane during its development are shown in plate 11, figure 1, which is an interior view of one arrangement which accommodates 30 passengers, and plate 10, figure 2, which illustrates, in a construction view, the unique manner in which structural provision for pressurization is provided, accompanied by provision for tremendous bulk of baggage, express, and freight under the cabin floor. An idea of the size of the plane is shown in plate 11, figure 2, where one of its four gas tanks is set beside a two-place training plane; the tank is almost as large as the entire fuselage of the training craft. Plate 12 is a view of the plane in flight over New York City. This plane will provide still higher standards of safety and economy in operations.

The final illustrations of this paper are views of the most modern equipment now flying; the beautiful Boeing Pan American Clipper (pl. 13, fig. 1) and the Douglas DC–4 (pl. 13, fig. 2). Last of all, two views illustrating a prediction of Mr. Sikorsky of the trans-Atlantic airliner of the future, plate 14, figure 1, showing the dining salon and plate 14, figure 2, the flying boat itself in the air.

CONCLUSION

We have thus reviewed transport aviation, showing its history from "infancy" to 1911, through "romantic childhood" to 1926; "painful adolescence" to 1931; its satisfactorily progressing "young manhood" to the present time; and its promise of "maturity" for the future. One cannot but be inspired by contemplating some of the following:

A recent TWA timetable schedule headed "Europe—New York—Chicago—Los Angeles—San Francisco—Asia."

The growth of one of the United States air systems, American Airlines, Inc., from its first passenger in April 1927, to its millionth in February 1937, and its two millionth in September 1939.

The fact that our domestic air lines are now flying over 250,000 plane-miles each day; the equivalent of 80 round trips from New York to Los Angeles or of 10 trips around the world at the Equator, or perhaps better still, one to the moon.

The fact that there are 30 large airlines flying daily each way on scheduled trips between New York and Chicago (a greater number than holds for through-train schedules).

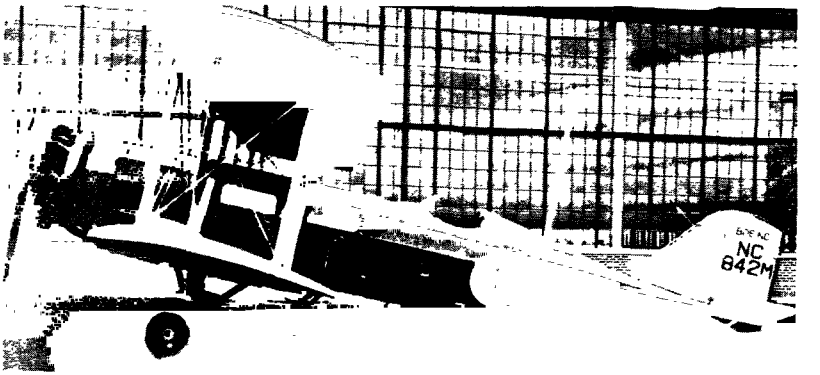
The fact that we are now enjoying regular service coast to coast in just under 17 hours which we may confidently expect will, within a reasonable time, be reduced to 12; and regular trans-Atlantic trips of 24 hours' duration at present which will be cut eventually to 18.

These factors are all indicative of the inspiring future of air transportation.

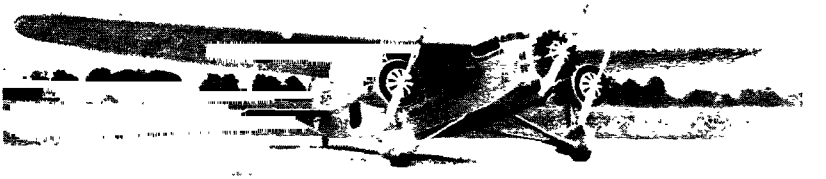
I cannot close without again referring to my belief that this bringing of peoples closer together will be a tremendously important factor in maintaining the peace of the world once the present war is over. This vision was, strangely enough, first pronounced almost a hundred years ago by William S. Henson, the inventor of an "aerial steam carriage" in 1843. His vision of the airplane as represented mechanically in his invention was remarkable in its close approximation in many respects to our present-day airplanes, but what he wrote concerning his vision of human relations as affected by his invention is even more important and is quoted below:

* * * The changes which must follow the first aerial voyage of one hundred miles in length must be great, may be astounding to our present notions, may be dashed as all human advances are with subtractive evils, but they must be largely beneficial to the human family. It is no considerable earnest of future good that the very nature of the design compels us to consider all mankind as one community * * * when men are strangers, they are ready to become enemies; render them mutually acquainted, and they soon become mutually useful, and when their interests are at stake we may safely reckon on their continued and abiding friendship. * * *

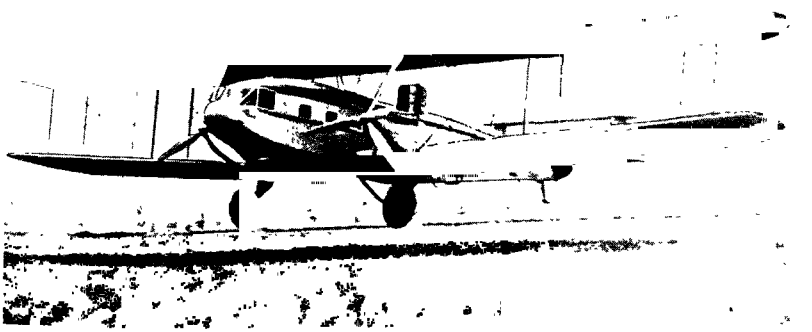
Let us continue to improve our air-transport planes and our air-transport services. Let us see that the objectives finally accomplished are those envisioned above. And make certain that it shall not come to pass that the air conquers man, but that truly man conquers the air!



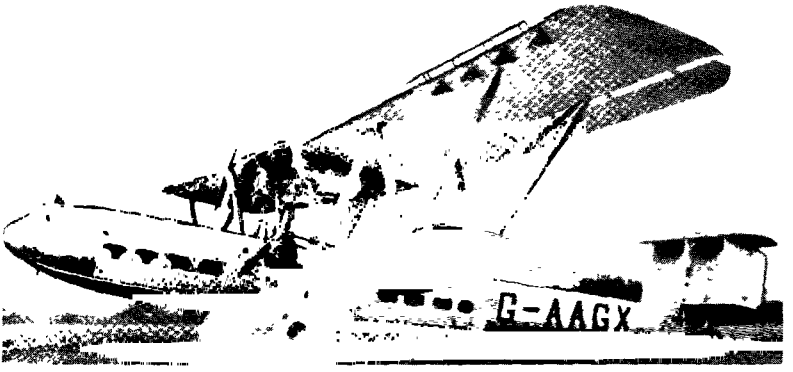
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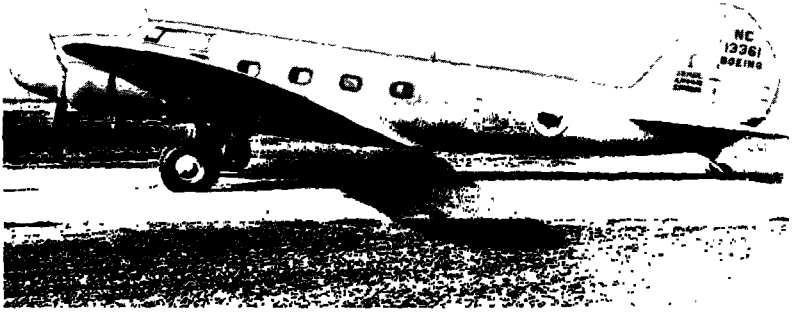
2 FORD TRIMOTOR



3. CURTISS CONDOR, 1930.



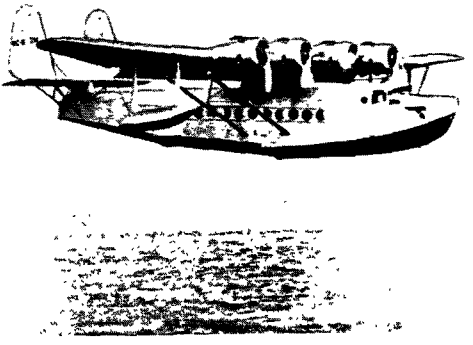
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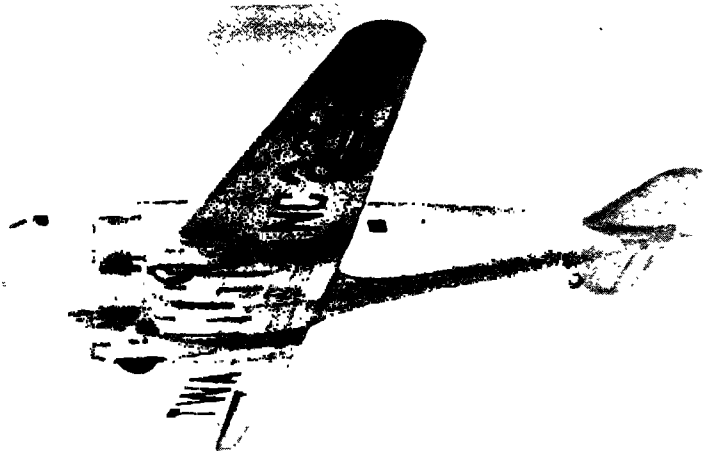
2. BOEING 247, 1934



3. CURTISS CONDOR SLEEPER, 1934.



1. SIKORSKY S-42, 1934.



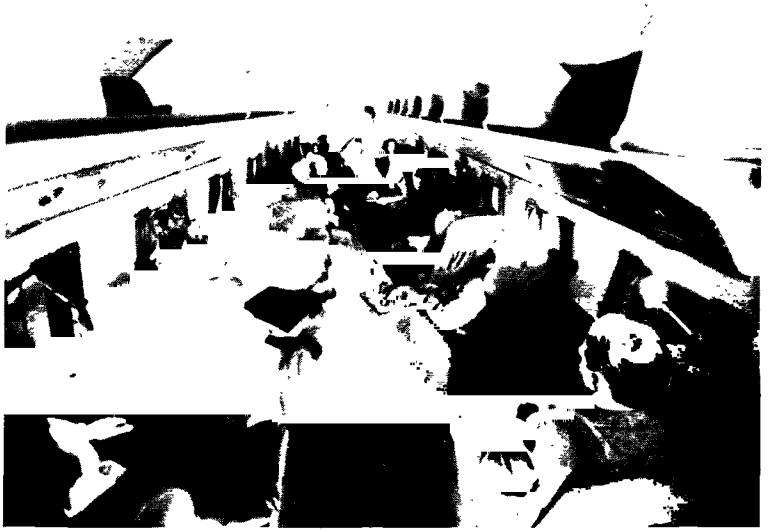
2. DOUGLAS DC-2, 1934.



1 MARTIN 130, 1935



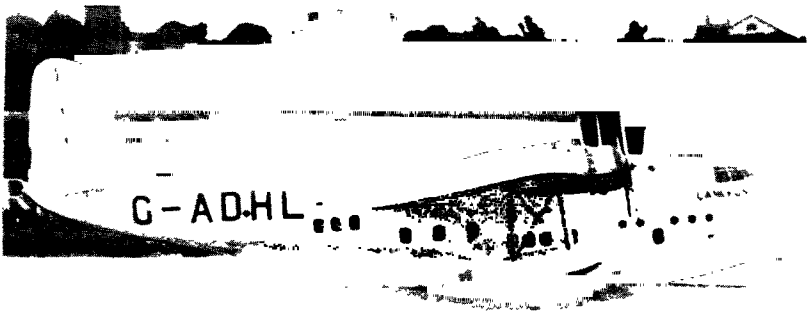
2 DOUGLAS DC-3 1936



1. INTERIOR OF DOUGLAS DC-3, 1937.



2. INTERIOR OF DOUGLAS DC-3 1937.



1. SHORT EMPIRE FLYING BOAT, 1937.



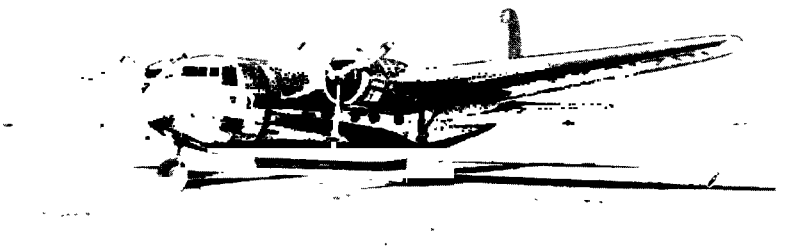
2. BOEING 314 CLIPPER, 1937.



3 INTERIOR OF BOEING 314 CLIPPER



1. LOCKHEED 14, 1937.



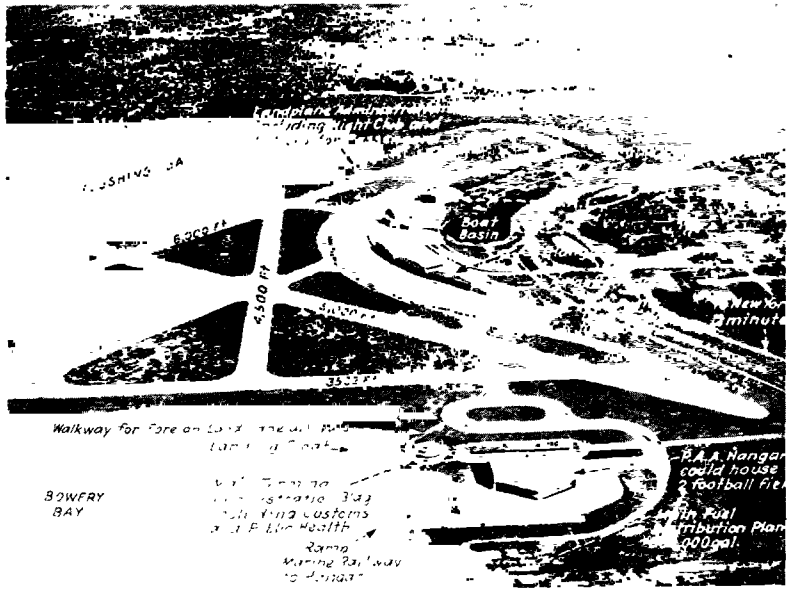
2 DOUGLAS DC-5, 1939.



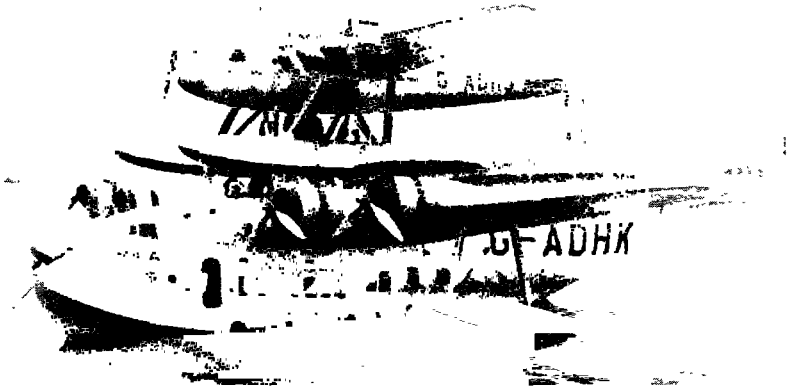
3. BOEING 307 STRATOLINER, 1939.



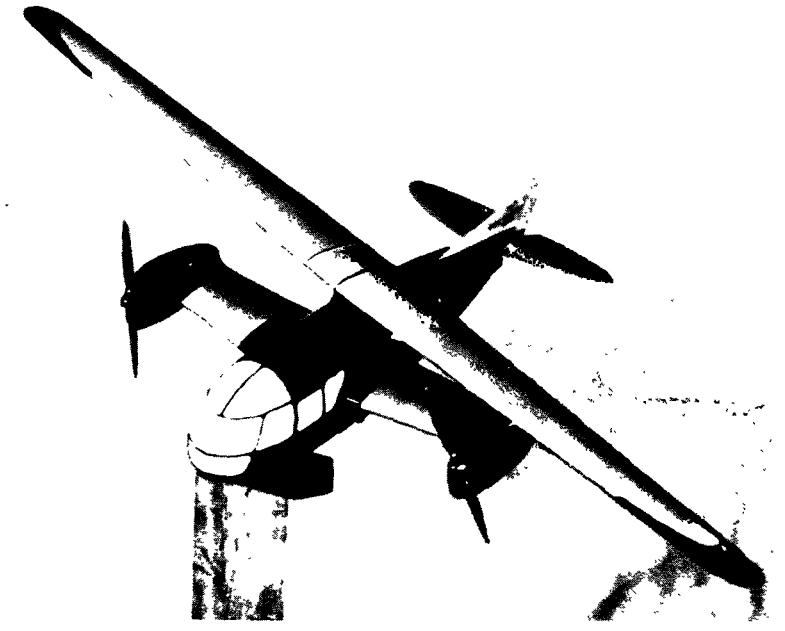
1 DOUGLAS DC-4, 1939.



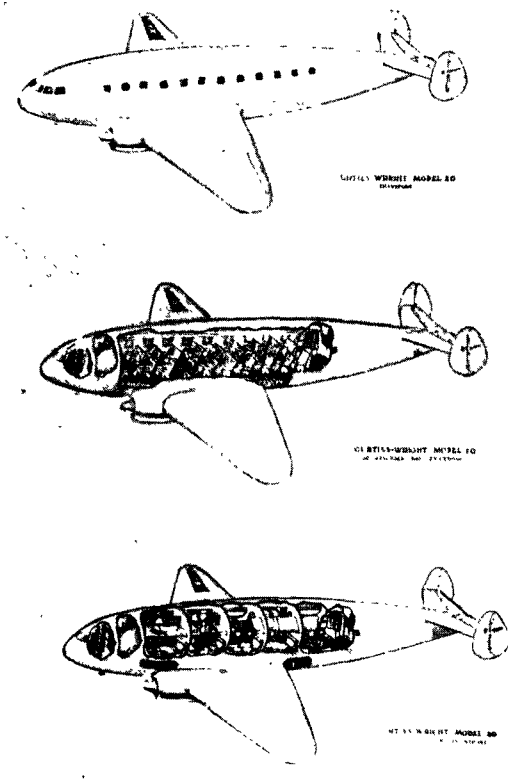
2 LA GUARDIA AIRPORT NEW YORK 1939



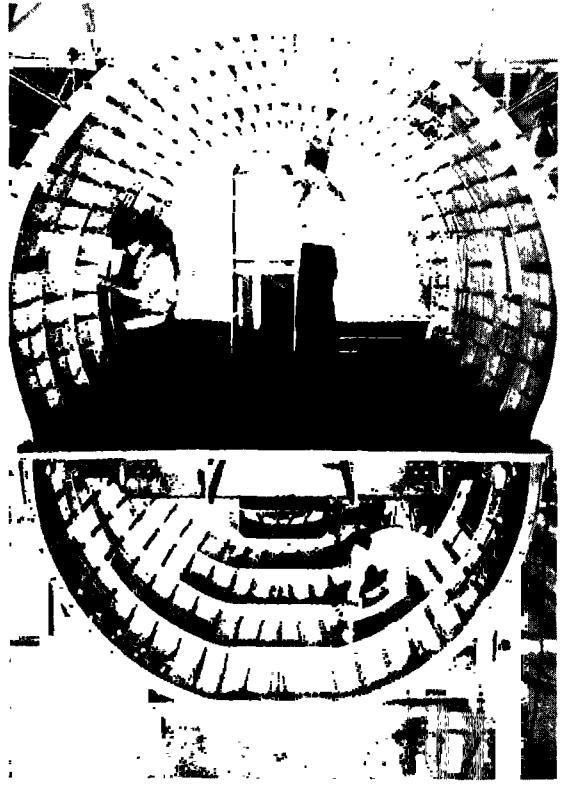
1. MAYO COMPOSITE AIRPLANE 1939



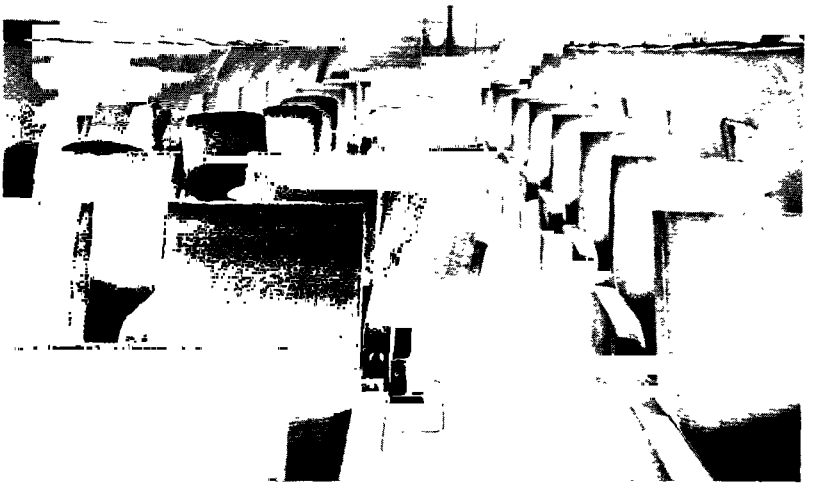
2. PROPOSED TRANSPORT HELICOPTER.



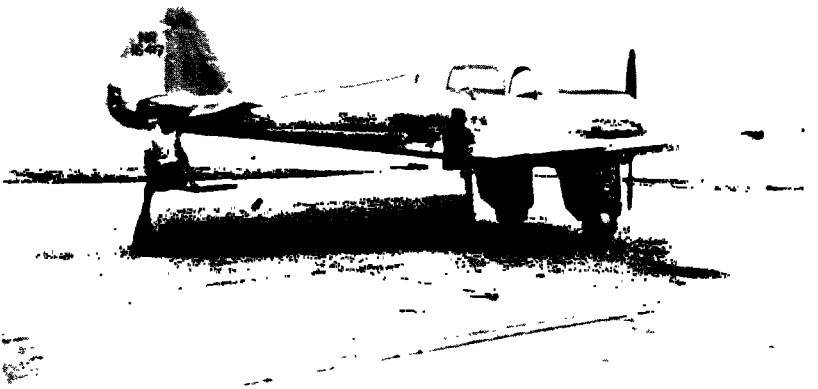
1. CURTISS-WRIGHT MODEL 20, 1940



2. CURTISS-WRIGHT MODEL 20.
Provision for pressurization and cargo space.

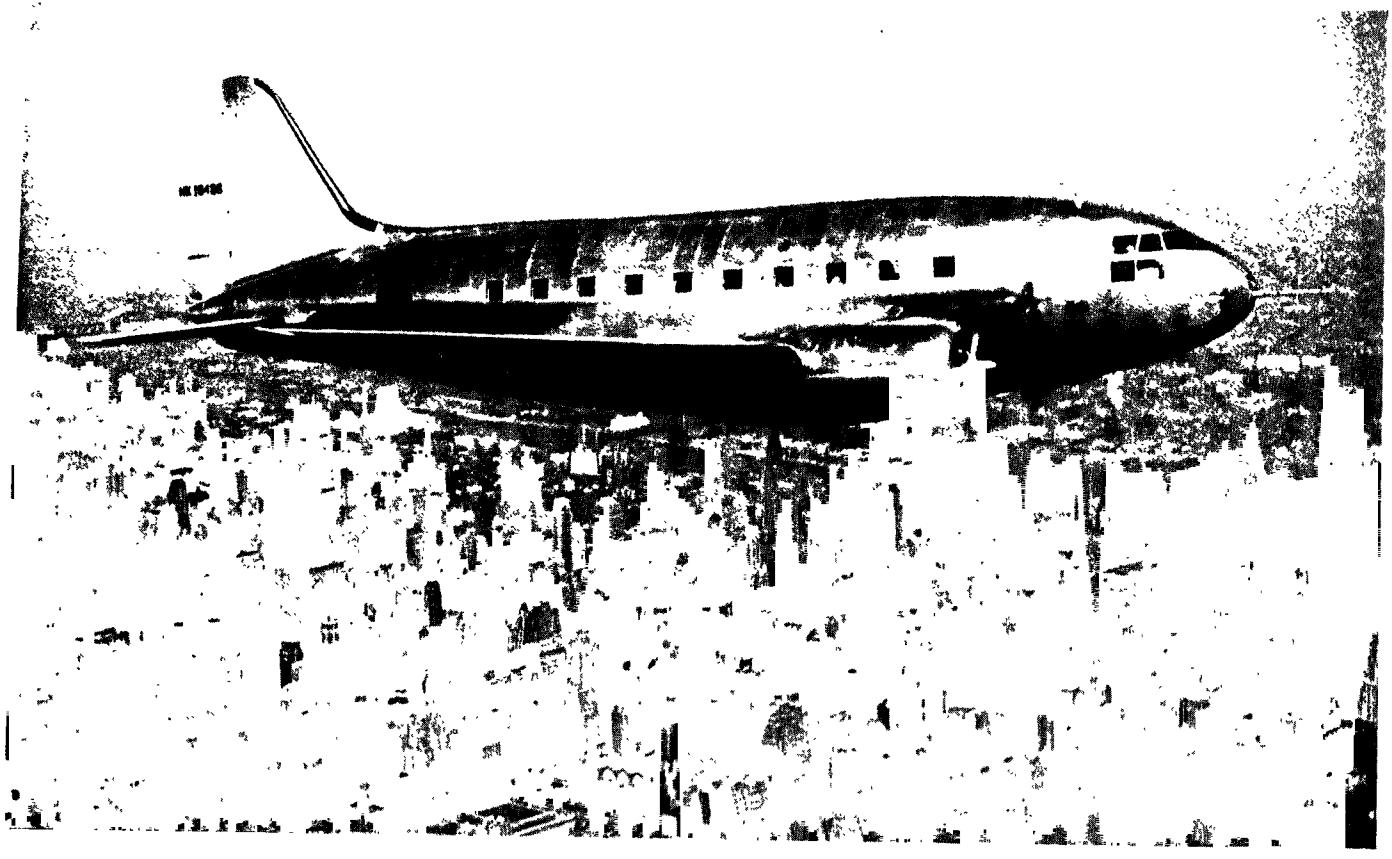


1. INTERIOR OF CURTISS-WRIGHT MODEL 20.

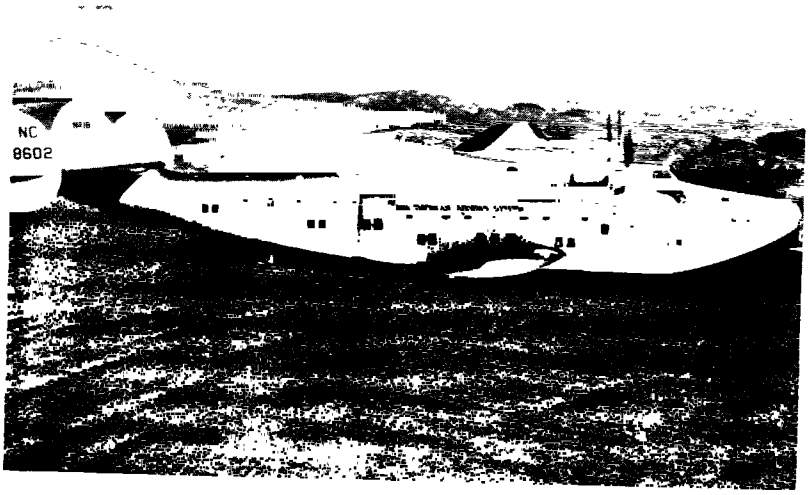


2. CURTISS-WRIGHT MODEL 20

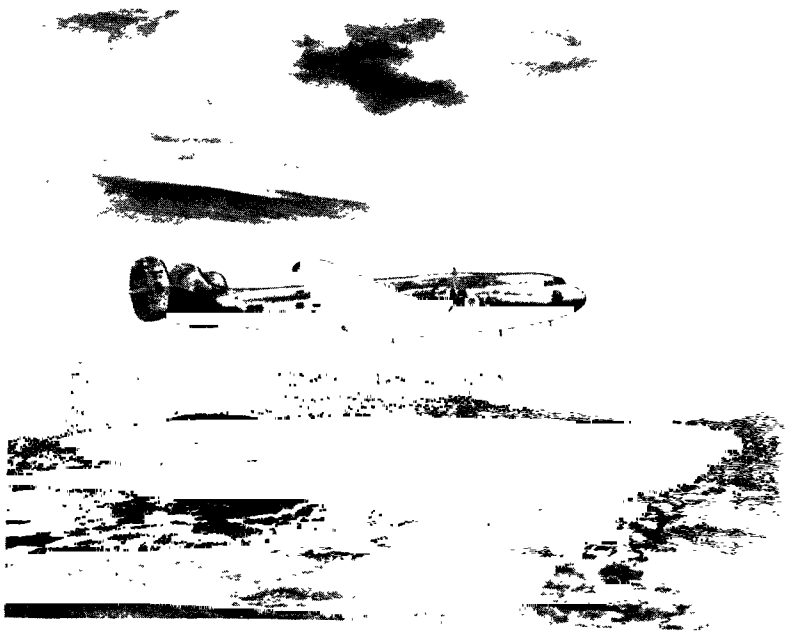
Fuel tank size comparison.



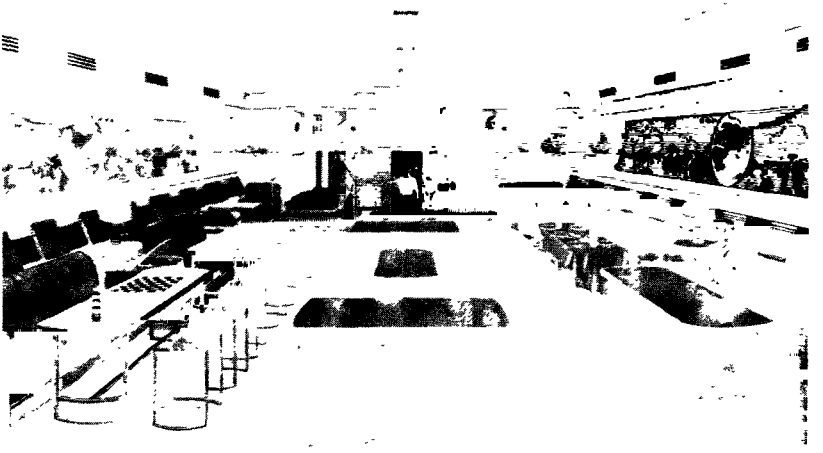
CURTISS-WRIGHT MODEL 20 IN FLIGHT OVER NEW YORK CITY.



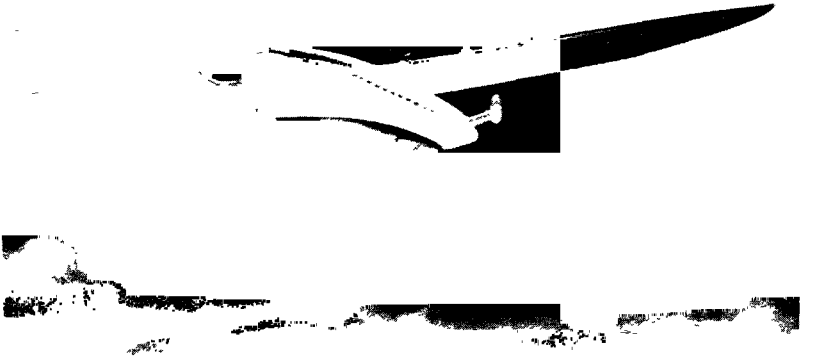
1. BOEING PAN AMERICAN CLIPPER.



2. DOUGLAS DC-4.



1 INTERIOR OF PROPOSED SIKORSKY OCEAN AIRLINER



2 PROPOSED SIKORSKY OCEAN AIRLINER.

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